MISSILE AND SPACE DIVISION

OPERATING AND MAINTENANCE INSTRUCTIONS

# DEVELOPMENT MODEL NON-MAGNETIC FLIGHT-TYPE MASS SPECTROMETER





GENERAL ELECTRIC

# OPERATING AND MAINTENANCE INSTRUCTIONS

# DEVELOPMENT MODEL NON-MAGNETIC FLIGHT-TYPE MASS SPECTROMETER

Contract NAS8-21217

for

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Huntsville, Alabama
35812

Apollo Systems Department
Missile and Space Division
General Electric Company
Daytona Beach, Florida
32015

# TABLE OF CONTENTS

## I. GENERAL INFORMATION

This Operations and Maintenance Manual covers the feasibility model of a ruggedized mass spectrometer. This equipment has been developed to prove that a ruggedized design of a monopole type mass spectrometer can be made. The emphasis was on ruggedizing the mass spectrometer tube and its associated electronics employing vibration isolators as needed. The ion pump has not been ruggedized and must be removed from the instrument case during all vibration testing.

A description and theory of operation has been included in the final report on this program and will not be repeated here.

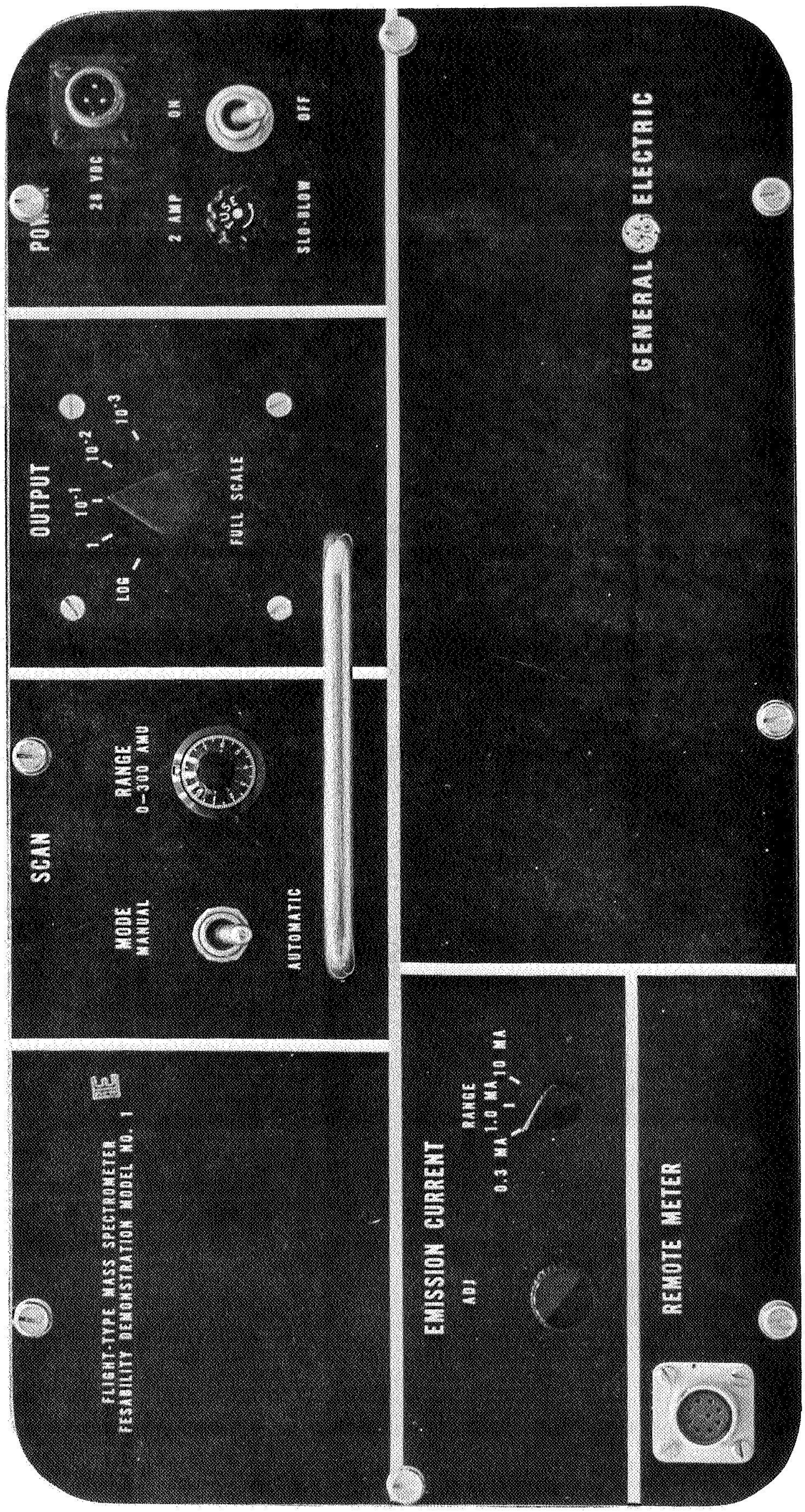
Because this is a feasibility model, some non standard components are included, although, where practical, standard components have been used.

## II. OPERATING INSTRUCTIONS

This system is a feasibility demonstration model of flight hardware. The unit may be operated in a laboratory environment and a vibration environment as specified in the final report on this project. Ruggedization was considered the most stringent specification on a flight type mass spectrometer. The requirements of operation over a wide temperature range are not intended to be met by the model and temperature tests should not be conducted. It is anticipated that temperature compensation will be a straightforward design problem and therefore can be accomplished in a flight hardware phase without prior demonstration by a feasibility model.

The following sections indicate general operational procedures for this unit. Controls are provided (Figure 1) in order to test the unit in accordance with various applications, so this unit has more flexibility than an end flight hardware product would be expected to have.

Since this model is a one-of-a-kind product, not all procedures can be rigidly specified. It is expected that the operator will use these following procedures as general guidelines which can and are expected to be modified as the operator gains experience. This unit should be considered as an item for testing and observation with the purpose of demonstrating the good points and limitations of this type instrument in aerospace monitoring applications.




Front Panel

FIGURE 1

## 2.1 BAKEOUT AND EXHAUST

### 2.1.1 Exhaust

The flight-type mass spectrometer system is capable of sustaining an internal operating pressure of $10^{-6}$ torr while sampling through the inlet provided. The power for the ion pump operation is provided by the system electronics. Before operation can begin, the system must be exhausted by an auxiliary vacuum pumping system through the roughing port on the spectrometer envelope. The system must be capable of providing a minimum pressure of $10^{-5}$ torr within the spectrometer while pumping through the 6 liter/second valve installed on the roughing port.

After the pressure has reached $10^{-5}$ torr the ion pump can be actuated by an accessory-5KV power supply which is capable of providing up to 10 ma of current.

This supply will furnish the necessary current for pumping to $10^{-6}$ torr at which time the built-in supply will sustain operation.

### 2.1.2 Bakeout or Degassing

Bakeout is necessary to degas the mass spectrometer system for high vacuum, low background operation. The rate of heating or cooling is not critical. Heating tape should be wrapped around the tube and ion pump ports. One layer of the heating tape provided is adequate. The temperature must be monitored by a thermocouple mounted to the tube envelope. The temperature can be controlled by a rheostat which controls the power to the heating tape.

Although the rate of heating in itself is not critical, it must be controlled to prevent the pressure in the tube from rising too high. The tube should be pumped to at least $1 \times 10^{-5}$ torr. To prevent oxidation of the elements, the temperature should then be controlled so that the tube pressure does not exceed $5 \times 10^{-5}$.

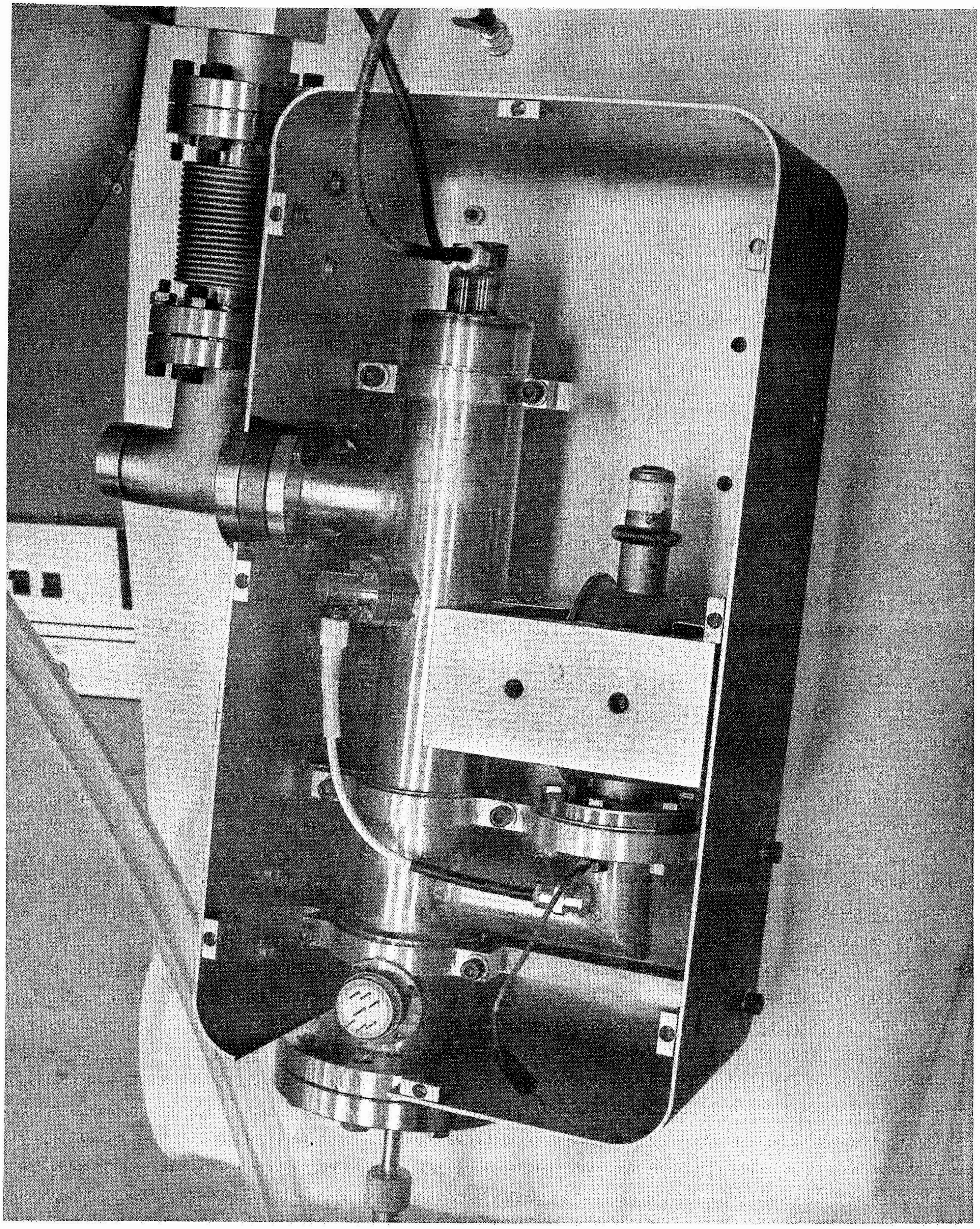
> NOTE: This is especially important when the tube is baked for the first time or after it has been exposed to atmospheric pressure.

If the laboratory vacuum system contains a molecular-sieve trap or other device which can absorb moisture during exposure to atmosphere, provision should be made for baking out this device also while it is isolated from the tube. This prevents exposure of the electron multiplier to relatively high water-vapor pressures from the trap. If, despite precautions, exposure to atmosphere does occur, the tube can be restored to satisfactory operating condition by rebaking it.

If the laboratory system is an oil free, water free system, the spectrometer can be degassed directly to the system through the valve on the roughing port. If there are contaminents in the system, the tube must be degassed to the ion pump. In this case, a separate-5KV power supply must be used to provide sufficient current during bakeout.

A list of steps for exhaust and bakeout follows:

1. Connect the valve port to a high,vacuum oil-free, water-free, laboratory pumping system. Figure 2.
2. Remove front panel and disconnect electronics. See Section 2.2.
3. Wrap the spectrometer and ports with heating tape controlled by rheostats and monitored by a thermocouple gage.
4. Attach hose to auxiliary mechanical pump and to valve on leak and actuate pump.
5. Open valve after evacuating hose.
6. Actuate the primary pumping system.
7. After the pressure in the spectrometer has reached $10^{-6}$ torr, turn on the heating tapes.



Spectrometer Mounted in Case

FIGURE 2

8. Monitor the temperature and pressure. The pressure in either tube must not exceed $5 \times 10^{-5}$ torr. The temperature on model #1 must not exceed 150°C. The temperature on model #2 must not exceed 200°C.

9. Continue heating and pumping until the pressure in the tube has decreased to less than $10^{-6}$ torr.

10. Turn off heating tape and remove from tube.

11. After cooling, make certain all bolts on flanges are secured.

12. Attach electronics.

13. Turn power on.

14. Close off roughing port valve.

15. Shut off valve on leak.

16. Disconnect valve from leak.

## 2.2 OPERATIONAL PROCEDURES

### 2.2.1 Initial Start-up Procedure

NOTE: For greater safety, plug in the power cord only AFTER pre-setting the controls.

The initial start-up procedure can be carried out with a strip-chart recorder to display the output of the Electrometer Amplifier (J-3 and J-4 on the meter panel). For the procedure using strip-chart recorder, see paragraphs 2.2.2 through 2.2.7.

### 2.2.2 Initial Start-up Using Strip-chart Recorder

The following steps describe the procedure for an initial start-up using a strip-chart recorder for readout:

1. Resistance of Feedthroughs to Ground-- With the tube mounted in the system, check the resistance of the feedthroughs to ground. Resistance should be infinite on all except the one labeled H.V. (high voltage). Resistance on the "HV" feedthrough should be 16 megaohms.

2. Vacuum-- Vacuum in the system should be 1 x $10^{-6}$ torr or better.

3. Power-- The Power switch should be OFF.

4. Tube Connections-- The following connections must be made:

   (a) Connect the high-voltage cable to the receptacle on the power supply module.

   (b) Connect the collector cable to the input of the electrometer amplifier labelled COLL.

   (c) Connect the white R-F cable to the connector labelled "RF".

   (d) Connect the meter output to the input of the meter box. Turn Sw. S-1 off. Connect the recorder output to the recorder (0 to 10V). If S-1 is on, output is 0 to 5VDC.

   (e) Connect the end of the ion source cable to the analyzer tube.

(f) Connect the ion pump power cable.

### 2.2.3 Switches and Controls Pre-Settings

The following pre-settings are required on the switches and controls listed:

1. Mass Scan
   (a) Scan Selector Switch-- MANUAL
   (b) Manual Scan Control-- fully counterclockwise
2. Ion Source Control
   (a) Emission Current ADJUST-- fully counterclockwise
   (b) Emission Current RANGE F.S. Switch-- .3 ma
3. Accessory Equipment:
   (a) If the strip-chart recorder has a variable input, adjust the input setting to be compatible with the electrometer amplifier output, i.e., so that the deflection on the amplifier and the recorder are equal. When the amplifier is at full scale deflection, the recorder should also be at full scale deflection.
   (b) Set the electrometer amplifier attenuation scale to match the pressure, e.g., with the system pressure at $10^{-1}$, set the output to give full scale deflection at $10^{-1}$ amperes.
4. Control Warm Up-- The following steps cover the procedure for warming up the control prior to initial operation:
   (a) Connect external 28 VDC, 2 amp, with an ammeter.
   (b) Turn ON the Power switch.
   (c) Turn ON the strip-chart recorder.
   (d) After a warm-up time of five minutes, proceed to tuning. Do RF as in paragraph 2.2.4

### 2.2.4 R-F Tank Circuit Tuning Procedure

The following steps comprise the procedure for tuning the RF Tank Circuit:

1. Rotate the MANUAL SCAN control (ten-turn helipot) clockwise until there is a deflection on the Mass Meter of approximately half of full scale. (S-2 on meter box must be on).
2. Adjust the RF tuning control located on the front side of the unit until a minimum current reading on the 28 VDC input is observed.
3. Rotate the MANUAL SCAN control clockwise to full scale (mass 300) and again adjust the RF TUNING control for minimum current. When this point is reached, the RF Tank Circuit is properly tuned.
4. Rotate Manual Scan control fully CCW.

### 2.2.5 Check Ion Source

The following steps cover the procedure for tuning the Ion Source control:

1. Using the emission control located on the front panel, adjust the Emission Current to 1 ma as observed on the Emission meter.
2. Turn the SCAN switch to automatic and record a spectrum 0 to 300 AMU.
3. If peaks do not appear on the recorder paper by the time mass 50 is reached, repeat the scan at a more sensitive setting of the electrometer amplifier.

### 2.2.6

The instrument is now properly set up for operating with the strip-chart recorder display of the analyzer tube output. This procedure can also be used with an oscilloscope or x-y recorder by applying the electrometer amplifier output to the vertical input and the mass scan voltage to the horizontal input. This will provide a display with mass 1 on the right hand side of the screen. The initial start-up procedure is the same as above except as noted. Switch S-2 must be off for this procedure.

### 2.2.7 Operation

After completion of the initial start-up procedure, other settings of the emission current can be used to change the performance of the instrument for calibration purposes.

### 2.2.8 Factors Affecting Operation

Some of these variations in settings and their effect on the instrument's performance are:

1. Output amplifier gain setting.
2. Increasing the emission current increases the number of ions formed and therefore the sensitivity.

### 2.2.9 Obtaining Working Knowledge of Instrument

With the instrument set up and ready for use, the operator should obtain a working knowledge of the instrument by experimenting with various settings and by familiarizing himself with:

1. Sensitivity variations with amplifier gain settings.
2. Emission current effects.
3. Choice of scan modes.

### 2.2.10 Short Period or Overnight Shut-down

The following steps comprise the procedure for shut-down for a short period or for overnight:

1. Turn OFF power switch.
2. Set the Scan Selector at MANUAL.
3. Set the Manual Scan (helipot) at 0/0 (fully counterclockwise).

### 2.2.11 Long-Term Shut-Down

The following steps comprise the procedure for complete shut-down of the instrument:

1. Set the Scan Selector switch on MANUAL.
2. Set the MANUAL SCAN helipot control at 0/0 (fully counter-clockwise).
3. Turn OFF power switch.
4. Turn OFF the auxiliary equipment.

## 2.3 CALIBRATION

This mass spectrometer has required calibration of the mass range and partial pressure output. The stability of the instrument can be monitored by determining how often these two parameters must be recalibrated.

The mass unit scale can be calibrated with an x-y or x versus time recorder. First a sweep speed may be selected which is compatible with the recorder being used in order to match the response time of the recorder. A spectrum may then be recorded and the peaks identified. In general, if the atmosphere is being sampled and the system is well outgassed, the largest peak will be at 28 which is $N_2^+$. Four units higher, at mass 32, $O_2^+$ will be a large contributor. Each of them will also show a doubly ionized peak at 14 and 16 respectively. $H_2O^+$ and $OH^+$ will give small peaks at 18 and 17 respectively. At higher mass units Argon will peak at $40^+$ and $CO_2^+$ at 44. From these peaks a curve can be drawn and the repeatability determined by successive runs.

The spectrometer atomic mass unit (AMU) scale is slightly nonlinear from 1 to 32. The scale is linear from 40 to 44 and maintains this linearity to 300 AMU. By extrapolating to higher masses the remainder of the scale can be roughly calibrated. To accurately calibrate at higher masses, mercury vapor or xenon may be introduced into the system. The AMU of all elements and compounds can be ascertained from a "Handbook of Chemistry and Physics," or any similar reference.

The calibration of the partial pressure output can be controlled by varying the emission current. This parameter is generally less stable than the AMU scale. The emission current control has been provided to correct the calibration and to vary the manner of calibration.

An easy method of calibration is to set the amplifier gain on 1. Adjust the emission current so that the $N_2$ peak is 7.8 volts on the recorder output when sampling a standard atmosphere. Since $N_2$ is 78% of the atmosphere, this setting allows calibration on $N_2^+$ and can be easily checked for stability. If the meter reading, 0 to 5 volts, is to be used, the height of the peak would be 78% of 5 volts or 3.9 volts. Any other gas near atmospheric pressure could also be used as a calibration standard.

In order to determine the partial pressure of the other gases present, the peak height must be corrected for the ionization efficiency of that gas with respect to the standard chosen. A discussion of ionization efficiencies can be found in "Scientific Foundations of Vacuum Techniques," Dushman and Lafferty, Second Edition, John Wiley and Sons 1962, page 321.

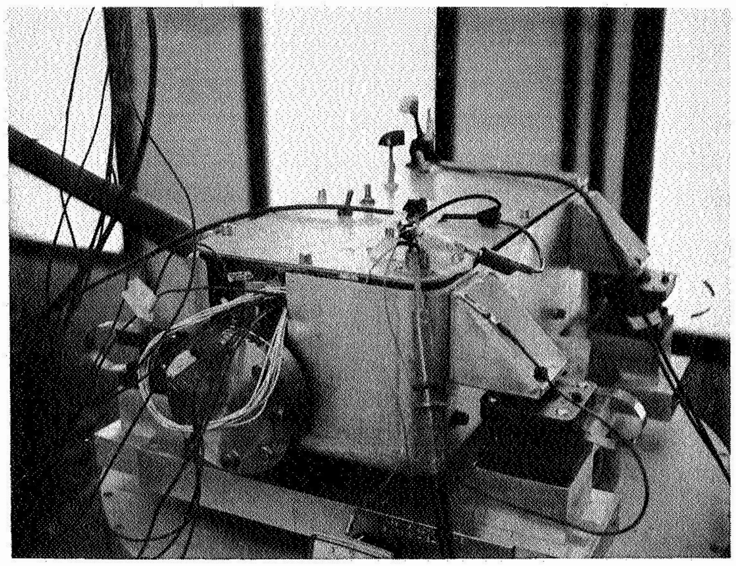
## 2.4 VIBRATION TESTING

The vibration testing for this system is complicated by the fact that one component, the ion pump, has not been ruggedized. For this reason the ion pump must be removed to a vibration free environment. This is done by attaching the pump or pumps to a flexible stainless steel vacuum hose which attaches to the roughing port of the mass spectrometer. The mass spectrometer ion pump port is closed with a blank flange.

The spectrometer system is mounted on the vibration isolators by gussetts which attach to the spectrometer box. Electrical connections can be made via the meter panel cable and 28 volt cable for operation and recording during vibration. The automatic scan mode must be used for obtaining spectra while vibrating. Figure 3.

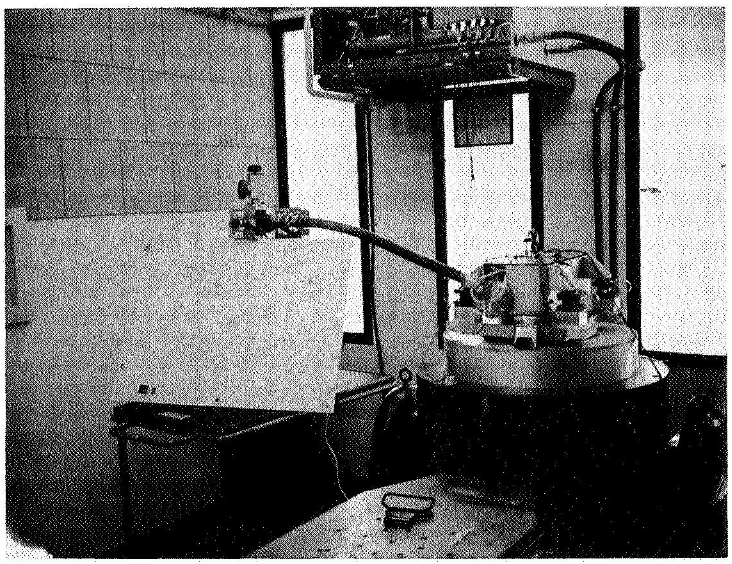
The required pumping speed for operation with the flexible hose is 16 liters/second. The extra 8 liter/second pumping requirement is to take care of outgassing from the flexible hosing. Two eight-liter-per-second ion pumps attached to a vacuum cross can be used for sustaining the low pressure during vibration. The procedure for vibration testing when using these pumps follows:

1. Remove ion pump from spectrometer.
2. Attach blank flange to ion pump port on the spectrometer.
3. Remove valve on roughing port.
4. Attach short flexible coupling to roughing port.
5. Attach 30" flexible hose to short flexible coupling. Figure 4.
6. Attach cross to flexible hose. Figure 5.
7. Attach two 8 liter/sec. ion pumps on two opposite arms of the cross. Figure 5.
8. To the remaining arm attach the bakeable valve. Figure 5.



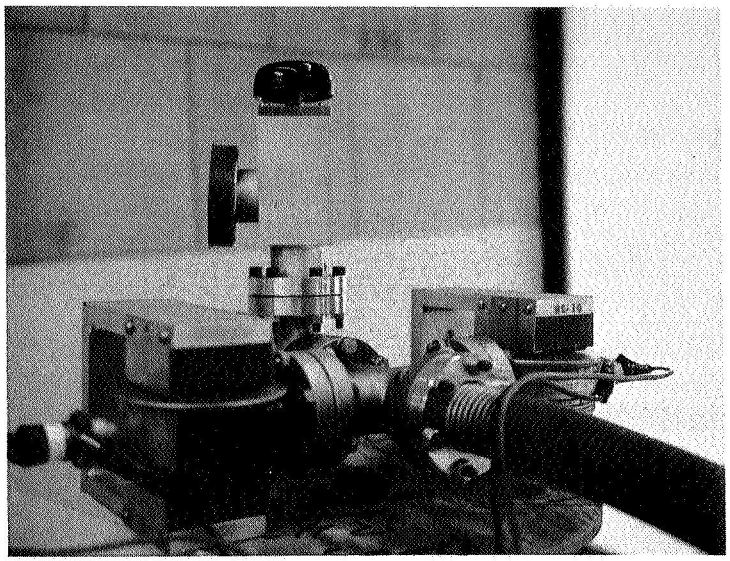
Vibration Tests of Mass Spectrometer System,
Unit on Vibration Stand

FIGURE 3



Vibration Tests of Mass Spectrometer System,
View of Flexible Hose

FIGURE 4



Vibration Tests of Mass Spectrometer System,
Ion Pump Arrangement

FIGURE 5

9. Attach valve to primary pumping system.
10. Follow steps 2-11 in section 2.1.2.
11. Attach leads from the auxiliary-5KV power supply to both ion pumps.

    EXTREME CAUTION SHOULD BE TAKEN IN THE USE OF THE HIGH VOLTAGE POWER SUPPLY AND ION PUMPS CONNECTED IN THIS MANNER.

12. Actuate ion pumps.
13. After observing low pumping current, shut off high voltage and disconnect the laboratory pumping system.
14. Actuate ion pumps. (The pumps can be turned off for a long time (hours) and re-started if the system has no leaks and has been baked out. This includes bakeout of the flexible hose which can be baked out at 300°C).
15. Follow operational procedures in Section 2.2 for proper electrical connections.
16. Tape ion pump connector to support structure in box.
17. Attach gussetts to box. Figure 3.
18. Attach gussetts to vibration isolators. Figure 3.
19. Secure ion pumps and all leads before beginning vibration.

# III. MAINTENANCE

Since this unit is a developmental instrument it has not been tested extensively. Field test data is generally needed to accurately predict probable failure modes. For this reason the troubleshooting of this unit can be treated only in a general manner. Some of the standard hardware included in this unit is treated more extensively.

## 3.1 SAFETY

### 3.1.1 Mass Spectrometer System

WARNING!

CARE MUST BE TAKEN AT ALL TIMES WHEN OPEATING THE MASS SPECTROMETER BECAUSE LETHAL VOLTAGES UP TO 5000 VOLTS ARE PRESENT.

ONLY OPERATORS FAMILIAR WITH THE HAZARDS ASSOCIATED WITH THESE VOLTAGES SHOULD CONNECT OR ADJUST THE INSTRUMENT.

ONLY TECHNICIANS FAMILIAR WITH SOPHISTICATED ELECTRONIC CIRCUITS SHOULD ATTEMPT TO TEST OR REPAIR THE COMPON-ENTS.

DISCHARGE ALL HIGH-VOLTAGE CIRCUITS TO GROUND BEFORE ATTEMPTING TO REMOVE LEADS OR TO CONNECT TERMINALS, TEST METERS, ETC.

WHEREVER POSSIBLE, MEASURE VOLTAGES BEFORE COMING DIRECTLY IN CONTACT AND BLEED OFF VOLTAGE THROUGH THE METER.

### 3.1.2 Ion Pump and Accessory High Voltage Supply

> WARNING:
>
> The voltages used with the pump can be fatal and therefore extreme care should be exercised when used. All high-voltage connections should be made by a connector with a grounded external shield. All floating electrical feedthroughs to the vacuum system should be grounded when the ion pump is started.

## 3.2 MASS SPECTROMETER TUBE

The spectrometer should not be disassembled for maintenance in the field. The reassembly is a complicated process requiring a trained technician supervised by a knowledgeable engineer. Many of the leads must be welded during assembly, and these leads are not easily accessible.

Since any maintenance must be performed by the Vacuum Products Business Section of the General Electric Company, no parts list is included in this Manual. Many parts have been specially designed and machined for this spectrometer and no duplicate parts are available. Some of the parts contained in these spectrometers are standard in the commercial Monopole 600 and are available in stock.

Some low level trouble shooting hints can be given, such as continuity checks. When all electronics have been disconnected, the following resistances should be measured.

Ion Source Connector

| Measurement | Value |
|---|---|
| Pin 1 to ground | open |
| Pin 2 to ground | open |
| Pin 3 to ground | open |
| Pin 4 to ground | open |
| Pin 5 to ground | open |
| Pin 6 to ground | open |

(If any of the above are not open, the spectrometer should be returned for repair)

| | |
|---|---|
| Pin 1 to 2 | 0.4 ohms |
| Pin 1 to 3 | 0.4 ohms |

(If either of the two values above are significantly different, re-wire the existing connector in the ion source board such that the other connection is made. Both leads are filament leads and an open or short indicates damage to the corresponding filament. If both are damaged, return the tube for repair)

If the sensitivity decreases and the electronics and bias settings have been checked, as discussed in Section 3.5, the electron multiplier gain may have changed. The resistance from the spectrometer high voltage lead, -3KV, to ground should measure 16 megohms. If it does not, the tube should be returned for repair. If the sensitivity is not regained upon further bakeout, possible dynode surface damage may have occurred and the tube should be returned for repair.

All flanges except the RF cable feedthrough flange may be removed. Special care should be taken to assure that no dust particles enter through the ports on the envelope. The red plastic caps furnished with the equipment should be placed over the open ports when the ion pump, valve, or leak flange is removed. Instructions for handling and care of the components mounted on the flanges of the spectrometer envelope are discussed in Section 3.3 and 3.4.

## 3.3 ION PUMP

The triode ion pump consists of a cellular stainless steel anode, two titanium sputter cathodes and two collector surfaces in a magnetic field (Figure 6). The cathode is operated at a high, negative potential with respect to the anode and collector.

An electron released by field emission at the cathode, is forced by the presence of the high magnetic field into a spiral path as it attempts to reach the anode. This results in a high probability of collision with a gas molecule, thus initiating ionization. Positive ions, drawn out of the volume defined by the anode cells, are accelerated toward the sputter titanium onto the collector surface. Since the cathode has an open structure, many ions also pass through. They are reflected by the potential of the collector, and return to the cathode and sputter material onto the anode surface. The ions strike the cathode with oblique incidence, resulting in a very high yield of sputtered titanium which effectively pumps the system by chemical combination with active gases and burial of inert gas molecules.

The ion pump is used to maintain a low vacuum in the mass spectrometer tube in the presence of low level outgassing in the system and the leakage through the sampling inlet. The ion pump supplied is a model 22TP152 manufactured by the General Electric Company, Vacuum Products Business Section. Figure 7. It has the following specifications:

| | |
|---|---|
| Speed | 8 liters per second |
| Pressure Range | $2 \times 10^{-2}$ to $2 \times 10^{-10}$ torr |
| Bakeout Temperature | 450°C |
| Life | 70,000 hours at $10^{-6}$ torr |
| Power Requirements | |
| (low pressure, starting) | 5 KV ; 70 ma |

When the mass spectrometer is ready to receive the pump, the copper gasket is placed in the constraining ring and the flanges brought together. Slight

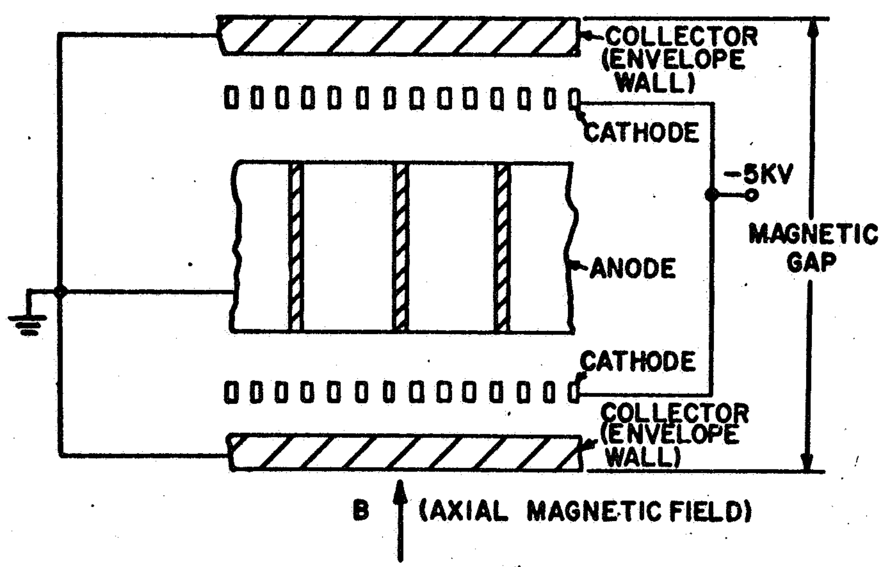



Fig. 6 Triode Ion Pump Schematic

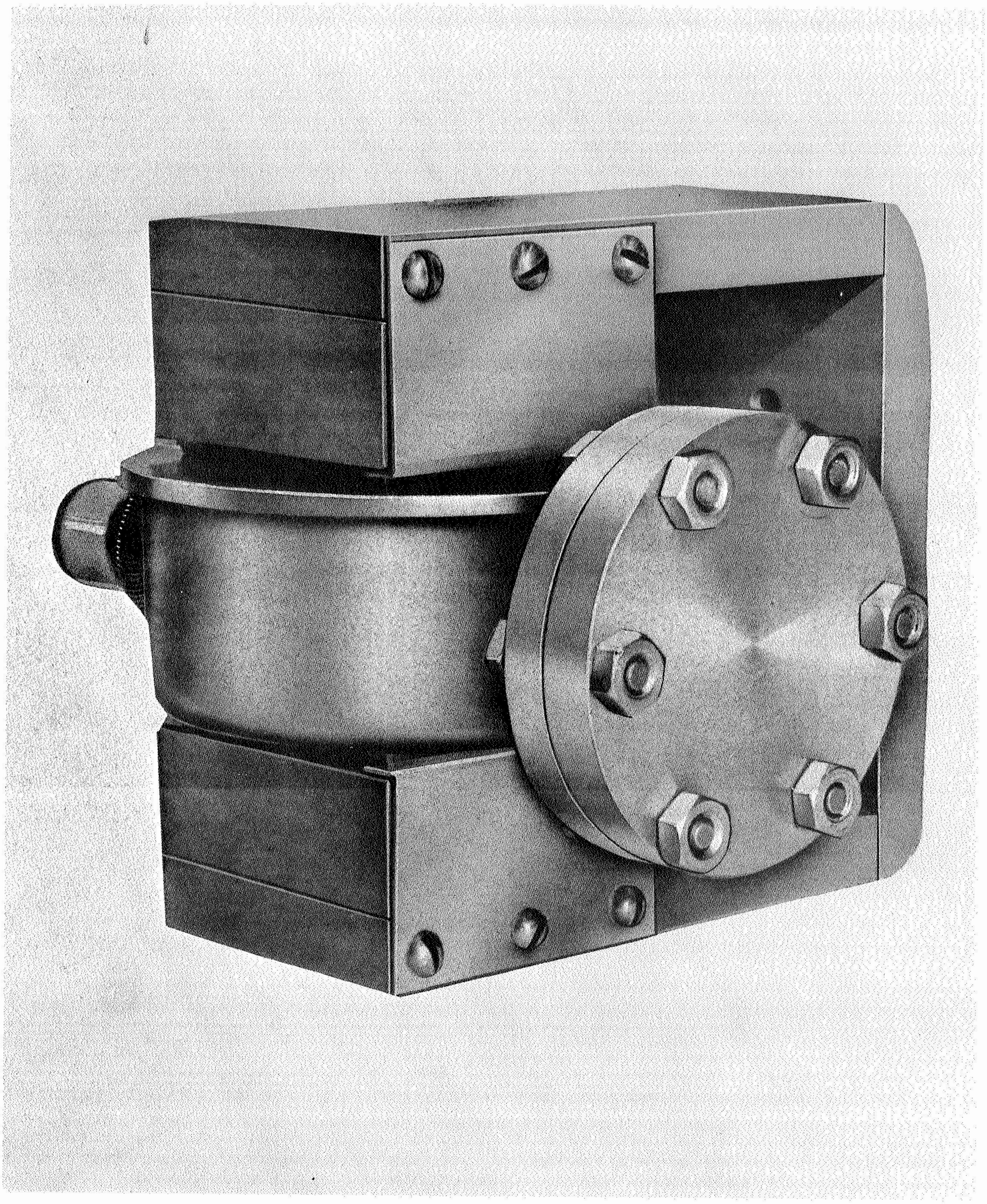


Fig. 7 8 L/S Triode Ion Pump

side-to-side movement of the pump will seat the gasket in the constraining ring of the mating flange. This is indicated by an audible click and restriction of the side-to-side movement. The seal is then completed by gradually taking up evenly and alternately on opposite bolts. A vacuum-tight seal will be obtained when a torque of approximately forty foot-pounds has been applied. The torque may have to be increased slightly with each successive re-use of the gasket.

One advantage of an ion pump is the absence of high-vapor-pressure organic materials. No fluids of any kind are required for operation of the pump and the use of metal seals between flanges eliminates organic gasketing materials and sealing greases. The elimination of these materials also permits the use of higher out-gassing temperatures.

To receive full benefit of this advantage and in order to achieve the speed and ultimate vacuum which the pump is capable of producing, it is strongly recommended that every effort be made to eliminate organic materials from the laboratory pumping system. Thus it is desirable during extended rough pumping to eliminate rubber-hose connections and to isolate diffusion-pumped leak-detecting apparatus from the system with adequate traps.

Reduction of the pressure in the system to 10 to 20 microns is required before the pump will start.

During use the pump may become contaminated and this is indicated by erratic behavior of a current meter, fluctuations of pressure in ranges heretofore stable, and internal sparking. If no leaks are present the pump should be cleaned. First, inspect the pump for flaking and contamination. If contamination is not severe, the pump may be cleaned as a unit in acetone or absolute alcohol, preferably using ultrasonic apparatus. Thorough rinsing in hot distilled or de-ionized water is necessary to remove all traces of organic material. After cleaning, pump parts which will see vacuum should not be handled with bare hands. Use nylon or lint-free paper. Store the modules in a clean, dry, hot atmosphere until the pump is ready for use.

For the lowest ultimate pressure in the ultra-high vacuum system the General Electric Triode Ion Pump can be "argon-processed" as follows.

A. Requirements

(1) Argon
(2) Ion pump operating (Pressure range $10^{-6}$- $10^{-9}$ torr)
(3) Ultra-high vacuum system - 200 C bakeout on ion pump.
(4) High-vacuum bakeable valve.

B. Argon Procedure

(1) Rough manifold down to 5 microns or lower.
(2) Fill roughing manifold with one atmosphere of argon.
(3) Leak argon into system to maintain approximately 3 x $10^{-5}$ torr pressure.
(4) Leak argon into system for 30 to 60 minutes with ion pump on.

## 3.4 VACUUM HARDWARE

Some standard items of vacuum hardware have been included with this unit. The maintenance of this component is discussed in the following section.

3.4.1 Block Valve (Figure 8)

The General Electric Viton-seal, high vacuum block valve is used for the connection between one spectrometer and the laboratory pumping system. Two Viton A "O" rings provide sealing, one as the seal-off and the other as the bellows to the valve body seal. These provide resiliency, low vapor pressure, and long life.

- Temperature Limits - In the open position, this valve can withstand temperatures up to 200 C.

- Conductance - Fully open, the conductance is 40 liters per second.

- High-vacuum Capability - This valve operates effectively to $10^{-9}$ torr.

- Connections - The Model 22HV125 valve has a 2-3/4 inch OD rotatable flange (Model 22HF115) on the side and end ports.

Acme thread on the valve stem assures rapid operation of the valve from fully open to fully closed. For ease in maintenance, the valve can be completely disassembled, without special tools, while it is still connected in the system. When replacing the stem and bellows assembly (see Table I, Item 4), lubricate the threads with "Never-Seez" compound. When replacing Viton "O" rings, clean them with a cloth dampened with acetone followed by a rinse in isopropyl alcohol. Do not let the acetone remain in contact with Viton any longer than is necessary.

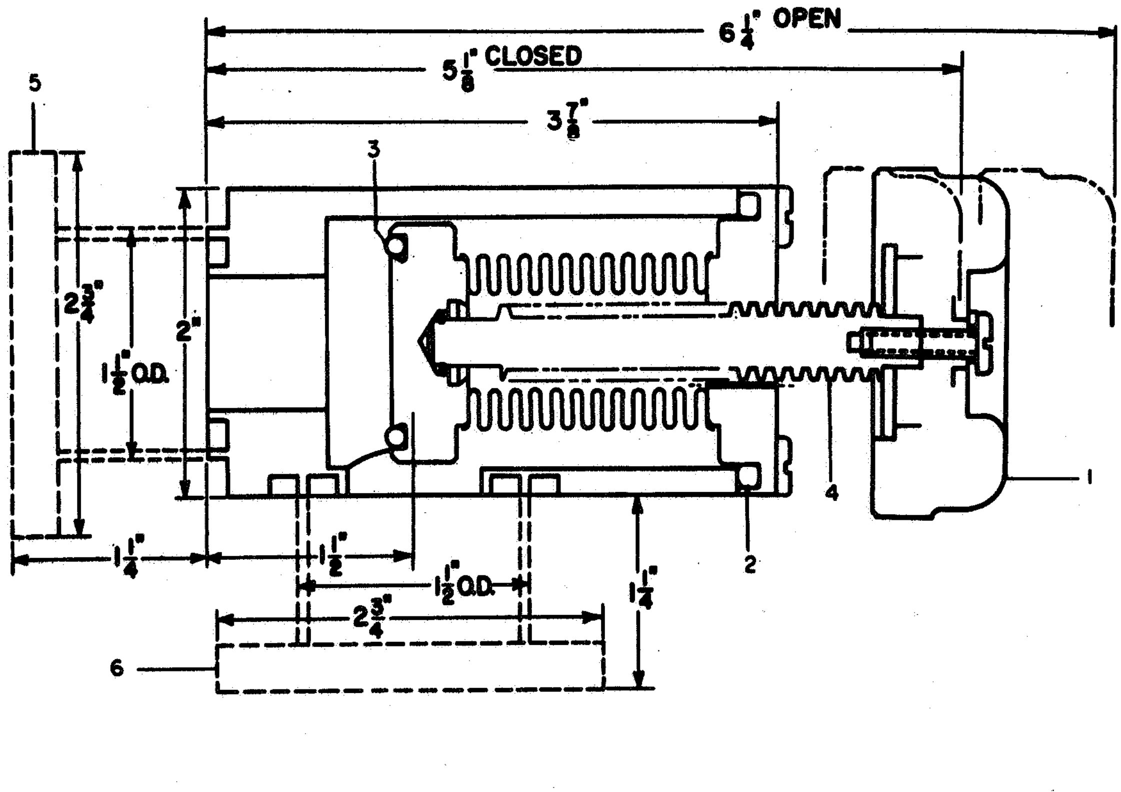



Fig. 8 High-vacuum block valve dimensions – Model 22HV125

### 3.4.2 Ultra High Vacuum Bakeable Valve

This valve is used for the connection between one mass spectrometer and the laboratory pumping system. The conductance of the valve in the fully open position is 6 liters/seconds. It is the model 22HV006A, manufactured by the General Electric Company, Vacuum Products Business Section. Figure 9.

The entire valve is bakeable either in the closed or open position, provided neither side of the sealing seat is exposed to an oxidizing atmosphere. The drive assembly does not require disassembly during bakeout but should be disassembled after the completion of the bakeout for relubrication of the driver screw. Relubrication can be carried out while the system is under vacuum, but the seat seal cannot be maintained during this procedure. The seat ball is replaceable, and the stainless steel seat is repairable.

When installing the valve, it can be given the desired orientation by loosening the seat flange screws just enough so that the seat and valve body flanges can be rotated to the proper position as one unit without disturbing the copper gasket. The seal flange can then be reseated by torquing alternate bolts by hand until a vacuum seal is assured. A final torque of 120 in lbs. should be applied to all bolts since after the valve is installed in the system, these bolts can be reached only by shutting down the system and removing the valve.

When closing the valve a torque wrench (20-150 in. lb.) should be used for the final closure. Only enough torque to effect a leak tight seal should be used. To open the valve use the demountable handle to back off the driver screw to the internal stop.

To lubricate the valve the following steps should be taken:

1. Adjust the driver screw so that the valve is almost, but not quite, fully closed.
2. Remove the three flush socket head screws (9) fastening the driver extension nut (10) to the valve body (11). Figure 9b

1. Driver screw
2. Driver screw nut
3. Handle
4. Seat ball
5. Seat flange
6. Gasket
7. Driver coarse threads
8. Driver fine threads
9. Socket head screw
10. Driver extension nut
11. Valve body
12. Seat flange screw
13. Ball cup screw
14. Bearing pad

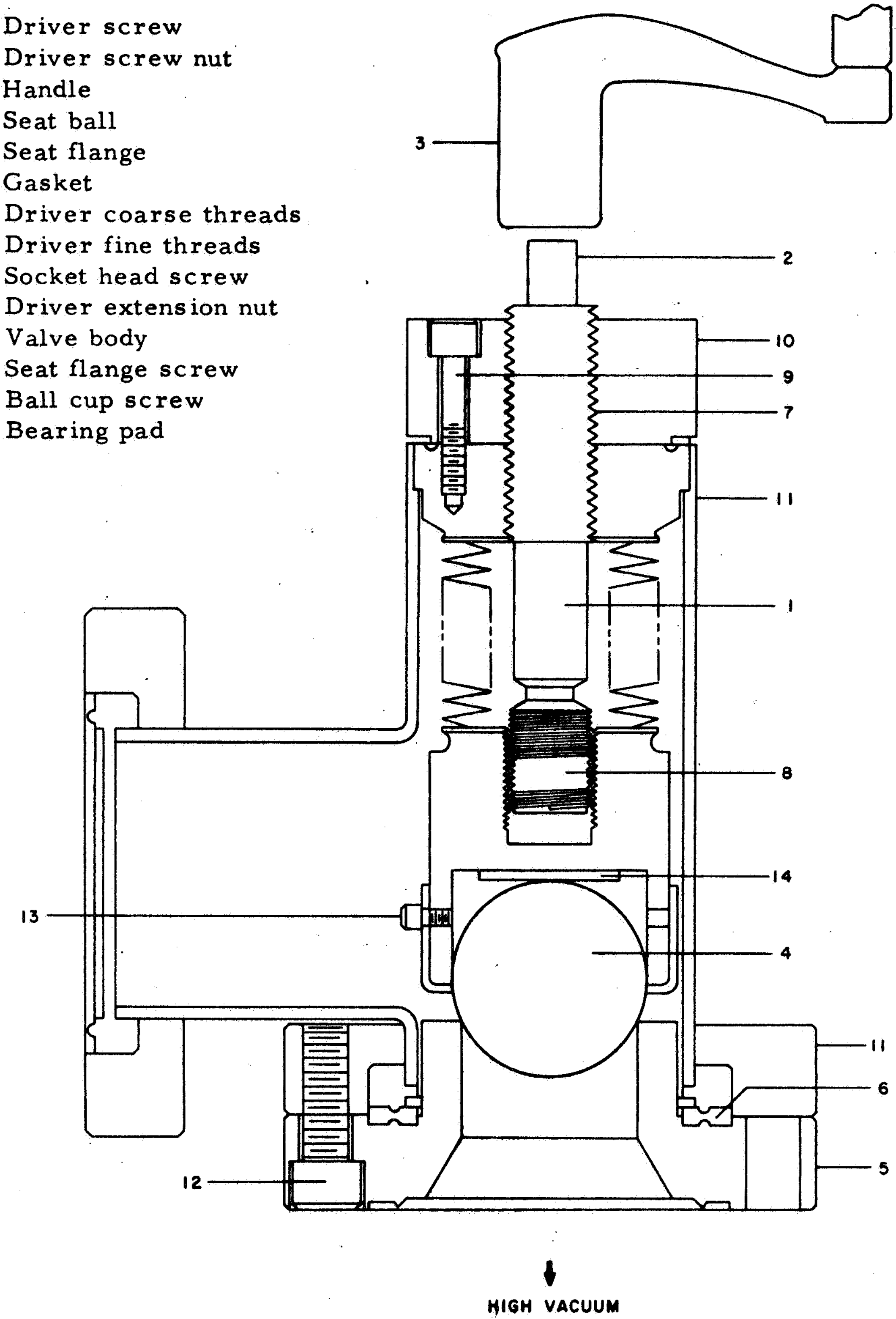



Fig. 9. Representative of 6 liters/second ultra-high vacuum bakeable valve

3. Remove the driver extension nut by rotating it counterclockwise.

4. As the extension nut is removed, gently lower the driver (1) until the ball (4) rests on the seat (5).

5. Remove the driver screw (1) by turning it counterclockwise.

6. Apply several drops of the special lubricant (Model 22HR015) supplied with the valve to both the fine threads (8) and coarse threads (7) of the driver screw and distribute it evenly over the threads.

7. To reassemble the driver:
   (a) Insert the driver screw back into the valve and screw the lower fine threads (clockwise) into the driver guide until they bottom.

   (b) Back off the driver screw three complete turns.

   (c) Start the driver extension nut (10) clockwise on the threads of the driver screw (1).

   (d) Depress the driver screw until the ball (4) is against the valve seat flange (5).

   (e) Complete screwing the extension nut on the driver screw until the extension nut is against the valve body (11), and the holes in the extension nut (10) align with the tapped holes in the valve body.

   (f) Position the extension nut by starting the socket head screws (9) into the tapped holes.

   (g) Before the socket head screws are tightened, back off the driver screw two turns to relieve any pressure on the valve seat flange during final tightening.

   This completes reassembly of the driver.

8. After each lubrication, recommended procedure is to apply a torque of 15 in.-lb several times to the driver prior to closing

the valve at a higher torque level. This is to provide for better conditioning of the threads by the special lubricant which was applied.

### 3.4.3 Sampling Leaks

Two sampling leaks are included for use with the two models of the mass spectrometer. These two leaks are slightly different in size to accomodate the difference in conductance from the mass spectrometer to the ion pump which is a result of different envelope configurations. Special copper gaskets are provided for attaching the leaks or blank flanges to the mass spectrometer envelope.

These leaks should be covered with the two small valves provided when the spectrometer is not in operation. The valve should be attached, evacuated by a roughing pump and closed in order to reduce sampling. The purpose is to keep the inlet free from contamination.

Inlets such as these have operated for several months with no change in conductance with proper handling. If the leak should become contaminated, the flange and leak assembly can be cleaned in an ultrasonic bath.

Clean first in an ultrasonic bath with detergents. Follow this by hot water and acetone. Finally clean in the ultrasonic bath with hot water and alcohol.

### 3.4.4 Accessory Vacuum Hardware

All other hardware, including the cross, flexible couplings, blank flanges and gaskets, should be maintained grease free. Care should be taken to refrain from touching these components within the seating grooves. The plastic caps should be kept on all exposed flanges.

If a piece of hardware should become contaminated, the part may be cleaned with acetone and alcohol. Bakeout at 200°C or greater, after connection in the vacuum system, will further clean the components.

## 3.5 ELECTRONICS

> **WARNING!**
>
> Lethal voltages up to 5000 VDC are present in the Mass Spectrometer. Only personnel trained in the safeguards for handling hazardous voltages should service this equipment.

### 3.5.1 Test Equipment

1. Simpson 260 Ohmmeter
2. Textronix 545 Oscilloscope
3. Textronix High Voltage Probe.
4. Kiethly Electrometer (610B) or eq.
5. Brush Oscillograph or eq.

### 3.5.2 Spare Parts

To provide effective maintenance of the mass spectrometer, a supply of critical components such as transistors, operational amplifiers, and diodes should be kept on hand.

3.5.3 Trouble Shooting Chart

| Trouble | Probable Cause | Remedy |
|---|---|---|
| | (1) MASS SCAN CONTROL | |
| (1a) Will not scan (manual) | (1) Low or no voltage | (1) Check center tap of R-1 on front panel. As R-1 is rotated the voltage should vary 0 to 7 volts. |
| | (2) Open or short wiring | (2) Check from CT of R-1 to pin 4MS-7. |
| (1b) Will Not Scan (automatic) | (1) Scan adjust pot. R15 of MS-6 out of adjustment | Re-adjust pot. |
| | (2) Open or short wiring | Check from Pin 10 MS-6 to Pin 4 MS-7 with S-1 in Automatic. |
| | (3) Defective amp. A-1 MS-6 | Check by substitution. |
| | (4) Defective Transistor $Q_1$ $Q_2$ $Q_3$ MS-6 | Check by substitution. |
| | (5) Defective diodes CR-1, CR-2 MS-6 | Check by substitution. |
| | (6) Scan Speed pot. misadjusted | Adj. for 060 sec.until sweep.Turn CCW until sweep. |
| (1c) (Automatic) Scan speed incorrect | (1) R-9 misadjusted | Adj.R-9 for proper scan speed (60 sec.) 0-300 AMU |

| Trouble | Probable Cause | Remedy |
|---|---|---|
| | (2) ION SOURCE CONTROL | |
| (1a) High Emission Current | (1) Short from transistor to heat sink | Check for defective insulation. |
| | (2) Shorted diode CR-1 | Check by substitution. |
| | (3) External short in cable or analyzer. | Check cable and analyzer for short. |
| | (4) Shorted transistor $Q_1$ $Q_3$ | Check transistors $Q_1$ $Q_3$ by substitution. |
| (2b) No Emission Current | (1) Open 70 volt supply, wiring. | Check wiring. |
| | (2) No reference supply. | Check zener CR-2 transistor $Q_4$ by substitution. |
| | (3) Meter Circuit not indicating current. | Check meter circuit |

## IV. AUXILIARY EQUIPMENT NEEDED

Roughing Pump System
8" x 16" x 6" or 7" stand
3/8" ID Vacuum Tubing
Mechanical Roughing Pump
X-Y Recorder
Light Pen Recorder
Thermocouple Gage
28-Volt Power Supply
5 KV - 10 ma Power Supply
Various Gas Samples
Vibration Test Equipment
Two Rheostats

## V PARTS LISTS

Note: Unless otherwise noted all parts numbers given are MIL

# PARTS LIST
# CIRCUIT BOARD MS-1
# REGULATOR

| | | | |
|---|---|---|---|
| R1 | 560 ohm, 1W | RC32GF561J | |
| R2 | 560 ohm, 1W | RC32GF561J | |
| R3 | 560 ohm, 1W | RC32GF561J | |
| R4 | 33 K, 1/2W | RC20GF333J | |
| R5 | 560 ohm, 1/2W | RC20GF561J | |
| R6 | 5.6 K, 1/2W | RC20GF562J | |
| R7 | 5.6 K, 1/2W | RC20GF562J | |
| R8 | 18 K, 1/2W | RC20GF183J | |
| R9 | 9.1 K, 1/2W | RC20GF912J | |
| R10 | 9.1 K, 1/2W | RC20GF912J | |
| R11 | 9.1 K, 1/2W | RC20GF912J | |
| R12 | 9.1 K, 1/2W | RC20GF912J | |
| R13 | 38.3 K, 1/2W | RN to C3832F | |
| R14 | 5.0 K, 1/2W | RC20GF502J | |
| R15 | 17.8 K, 1/2W | RN to C1872F | |
| C1 | 47 µF, 35V | CS13BF476K | |
| C2 | 100 pF | CM05D101J03 | |
| C3 | 10 µF, 35V | CS13BF106K | |
| C4 | 22 µF, 35V | CS13BF226K | |
| C5 | 0.68 µF, 50V | CTM684VAJ | |
| C6 | 4700 pF | CM06D472J03 | |
| C7 | 220 µF, 30V | CL25BH221UP3 | |
| L1 | 5 MH | P30-1 | Torotel |
| Q1 | 2N3702 | | |
| Q2 | 2N1711 | | |
| Q3 | 2N2905 | | |
| Q4 | 2N2905 | | |
| CR1 | 1N4449 | | |
| CR2 | 1N755A | | |

PARTS LIST
CIRCUIT BOARD MS-2
POWER CONVERTER II

| | | | | |
|---|---|---|---|---|
| C1 | 0.1 μF, 400V | | Sprague 91P1040452 | |
| C2 | 0.1 μF, 400V | | " | |
| C3 | 0.1 μF, 400V | | " | |
| C4 | 0.1 μF, 400V | | " | |
| C5 | 2.2 μF, 30V | ± 10% | Sprague 127P2259R34 | |
| C6 | 0.33 μF, 100V | | " 196P3340152 | |
| C7 | 2.2 μF, 100V | | CS13BJ225M | |
| C8 | 4.7 μF, 35V | | CS13BF475K | |
| C9 | 4.7 μF, 35V | | CS13BF475K | |
| C10 | 2.2 μF, 100V | | CS13BJ225M | |
| L1 | 100 MH | | MG50-14 | Torotel |
| L2 | 100 MH | | MG50-14 | Torotel |
| L3 | 5 MH | | MPF-051-10B | Collins |
| L4 | 5 MH | | " | " |
| L5 | 5 MH | | " | " |
| L6 | 5 MH | | " | " |
| L7 | 5 MH | | " | " |
| CR1 | | | MDA942-A5 | Motorola |
| CR2 | | | MDA942-A5 | Motorola |
| CR3 | | | MDA942-A5 | Motorola |
| CR4 | | | MDA942-A5 | Motorola |
| CR5 | | | MDA942-A5 | Motorola |

# PARTS LIST
# CIRCUIT BOARD MS-3
# POWER CONVERTER I

| | | | | |
|---|---|---|---|---|
| R1 | 560 ohm, 1W | RC32GF561J | | |
| R2 | 10 ohm, 1W | RC32GF100J | | |
| R3 | 2.2 K, 1W | RC32GF222J | | |
| R4 | 10 ohm, 1W | RC32GF100J | | |
| C1 | 10 µF, 35V | CS13BF106K | | |
| C2 | 2700 pF | CM06D272J03 | | |
| C3 | 250 µF, 10V | CL45BD251MP3 | | |
| T1 | Special Wound | 90T Pri. 60T-CT Sec. | | |
| T2 | 751 - 1052 - 100 | Scott Electronics Orlando, Fla. | | |
| CR1 | 1N4449 | | | |
| CR2 | VS 248 | Varo | | |
| CR3 | -5000V, voltage multiplier | | P/N SK-5191-000 | Erie Tech. Prod., Inc. |
| CR4 | -3000V, " " | | P/N SK-5192-000 | " " " " |
| Q1 | 2N3713 | | | |
| Q2 | 2N3713 | | | |

## PARTS LIST
## ELECTROMETER AMPLIFIER

| | | |
|---|---|---|
| R1 | 1000 ohms, 1/2W | RC20GF102J |
| R2 | 100K | RN65C1003F |
| R3 | 1M | RN65C1004F |
| R4 | 10M | Victoreen 507 |
| R5 | 100M | " |
| R6 | 1000M | " |
| R7 | 10,000M | " |
| R8 | 1000 ohm, 1/2W | RN65C1001F |
| R9 | 10K, 1/2W | RN65C1002F |
| R10 | 110 ohm, 1/2W | RC20GF111J |
| R11 | 180 ohm, 1/2W | RC20GF181J |
| R12 | 180 ohm, 1/2W | RC20GF181J |
| C1 | 1000 pF | CM06D102J03 |
| C2 | .1 50V | CTM104VAJ |
| C3 | .01 50V | CTM103VAJ |
| C4 | 1000 pF | CM06D102J03 |
| C5 | 100 pF | CM05D101J03 |
| C6 | 10 pF | CM05C100K03 |
| C7 | 5 pF | CM05C050K03 |
| C8 | 1 µF 35V | CS13BF105K |
| C9 | 1 µF 35V | CS13BF105K |
| A1 | Type 302 | Varactor Bridge Operational Amplifier, Analog Devices |
| CR1 | 1N4153 | |
| CR2 | 1N4153 | |
| CR3 | 1N759A | |
| CR4 | 1N759A | |
| S1 | PA6000 | Centralab |

PARTS LIST
CIRCUIT BOARD MS-5
ION SOURCE CONTROL

| | | | |
|---|---|---|---|
| R1 | 15K, 1/4W | RC07GF153J | |
| R2 | 56K, 1/4W | RC07GF563J | |
| R3 | 56K, 1/4W | RC07GF563J | |
| R4 | 8.2K, 1/2W | RC20GF822J | |
| R6 | 220 ohm, 1/2W | RC20GF221J | |
| R8 | 200K, Variable | 3051P1203 | Bourns |
| R9 | 200K, 1/2W | RC20GF204J | |
| R10 | 50K, Variable | 3051P1503 | Bourns |
| R11 | 200K, 1/2W | RC20GF204J | |
| R12 | 200K, Variable | 3051P1204 | Bourns |
| R13 | 200K, 1/2W | RC20GF204J | |
| C1 | 68 µF, 15V | CS13BD686M | |
| C2 | 68 µF, 15V | " | |
| C3 | 10 µF, 35V | CS13BF106K | |
| CR1 | 1N4449 | | |
| CR2 | 1N758A | | |
| Q1 | 2N1541 | | |
| Q3 | 2N1711 | | |
| Q4 | 2N2905A | | |

# PARTS LIST
# CIRCUIT BOARD MS-6
# SWEEP GENERATOR

| | | | |
|---|---|---|---|
| R1 | 10K, 1/4W | RC07GF103J | |
| R2 | 10K, 1/4W | RC07GF103J | |
| R3 | 100K, 1/4W | RC07GF104J | |
| R4 | 75K, 1/4W, 1% | RN65C7502F | |
| R5 | 3.3K, 1/4W | RC076F332J | |
| R6 | 30K, 1/4W | RC07GF303J | |
| R7 | 100K, 1/4W | RC07GF104J | |
| R8 | 15K, 1/4W | RC076GF153J | |
| R9 | 200K, 1/4W | 3051P1204 | Bourns |
| R10 | 1M, 1/2W, 1% | RN70C1004F | |
| R11 | 1M, 1/2W, 1% | RN70C1004F | |
| R12 | 1.5K, 1/4W | RC07GF152J | |
| R13 | 1K, 1/4W, 1% | RN65C1001F | |
| R14 | 39K, 1/4W | RC07GF393J | |
| R15 | 20K, 1/4W | 3051P1203 | Bourns |
| C1 | 5 pF | CM05C050K03 | |
| C2 | 1000 pF | CM06C102J03 | |
| C3 | 4.7 µF 35V ± 10% | CS13BF475K | Sprague |
| C4 | 2.2 µF 30V ± 10% | 127P2259R34 | Sprague |
| C5 | 47 µF 35V ± 10% | CS13BF476K | Sprague |
| C6 | 47 µF 35V ± 10% | CS13BF476K | Sprague |
| CR1 | 1N756A | | |
| CR2 | 1N4449 | | |
| A1 | µA709 | Fairchild | |
| Q1 | 2N2905 | | |
| Q2 | 2N2905 | | |
| Q3 | 2N2905 | | |

PARTS LIST
CIRCUIT BOARD MS-7
SCAN CONTROL 1

| | | |
|---|---|---|
| R1 | 5.1K, 1/4W | RC07GF512J |
| R2 | 1M, 1/2W | RC20GF105J |
| R3 | 10 ohms, 1/4W | RC07GF100J |
| R4 | 820 ohms, 1/2W | RC20GF821J |
| R5 | 10K, 1/4W | RC07GF103J |
| R6 | 10 ohm, 1/4W | RC07GF100J |
| R7 | 1K, 1/4W | RC07GF102J |
| R8 | 20K | RN65C2002F |
| R9 | 261K | RN70C2153F |
| R10 | 10K | RN70C1502F |
| R11 | 10K, 1/4W | RC07GF103J |
| R12 | 5.1K, 1/4W | RC07GF512J |
| R13 | 5.1K, 1/4W | RC07GF512J |
| R14 | 5.1K, 1/2W | RC20GF512J |
| R15 | 910 ohm, 1/2W | RC20GF911J |
| R16 | 1M, 1/2W | RC20GF105J |
| R17 | 2.26K | RN65C2261F |
| R18 | 10 ohm, 1/4W | RC07GF100J |
| R19 | 10 ohm, 1/4W | RC07GF100J |
| R20 | 1.5K, 1/4W | RC07GF152J |
| C1 | 390 pF | CM05D391J03 |
| C2 | 120 pF | CM05D121J03 |
| C3 | 220 pF | CM05D221J03 |
| C4 | 1 - 28 pF, 1200V | JFD Part No. MC623Y |
| C5 | 0.01 μF, 50V | CTM103VAJ |
| C6 | 47 μF, 35V | CS13BF476K |
| C7 | 1000 pF | CM06D102J03 |
| C8 | 0.01 μF, 50V | CTM103VAJ |
| C9 | 1 - 28 pF | JFD Part No. MC623Y |
| C10 | 47 μF, 35V | CS13BE476K |
| C11 | 0.1 μF, 50V | CTM104VAJ |
| C12 | 220 pF | CM05D221J03 |
| C13 | 0.1 μF, 50V | CTM104VAJ |
| C14 | 0.1 μF, 50V | CTM104VAJ |
| C15 | 4700 pF @ 100V | CM07D472J03 |
| C16 | 120 pF | CM050120J03 |
| L1 | 100 μh | 63A100324-25 |
| X1 | 1.8 MHertz Crystal | Texas Crystals CR18/μ |
| CR1 | 1N751A | |
| CR2 | 1N4153 | |
| A1 | QQ25AH Operational Amplifier, | Philbrick Researchers, Inc. |
| A2 | μA709 | Fairchild |
| Q1 | 2N1711 | |
| Q2 | 3N140 | |
| Q3 | 2N1711 | |

PARTS LIST
CIRCUIT BOARD MS-8
SCAN CONTROL 2

| | | |
|---|---|---|
| R1 | 100K ± 1% | RN65C1003F |
| R2 | 10K | RC07GF103J |
| R3 | 100K | 3051 P1104 |
| R4 | 2.05K ± 1% | RN65C2051F |
| R5 | 200K | 3051 P1204 |
| | | |
| C1 | 0.1 µF, 50V | CTM104VAJ |
| C2 | 10 pF, 3KV | 30 GA-Q10, Sprague |
| C3 | 10 pF, 3KV | 30 GA-Q10, Sprague |
| C4 | 0.01 µF, 400V | CPV09A1KE103K |
| C5 | 1-28 pF, 1200V | JFD Part No. MC623Y |
| C6 | 22 pF | CM05D220J03 |
| | | |
| L1 | 470 µH | 63A100324-33 |
| | | |
| Q1 | 2N1901 | |
| | | |
| T1 | Pri 6T Sec. 50T Core | F846-3-Q2 # 44 AWG |
| T2 | Pri 12T @ 2 Sec. 50T Core | F626-3Q2 # 32 AWG |
| | | |
| CR1 | Special Unitrode | |
| CR2 | " " | |
| CR3 | " " | |
| CR4 | " " | |
| CR5 | " " | |
| CR6 | " " | |
| CR7 | " " | |
| CR8 | 1N4449 | |
| CR9 | 1N4449 | |

PARTS LIST
FRONT PANEL

| | | |
|---|---|---|
| R1 | 20K | 20K ± 5%, ± 0.5% linearity, Bourns PN3507 5-1-203 with counting dial, Bourns PN H-493-3 |
| R2 | 25K 2W | RV4NAYSD253A |
| R3 | 8.2K 1/4W | RC07GF822J |
| R4 | 2.7K 1/4W | RC07GF272J |
| R5 | 820 1/4W | RC07GF821J |
| R6 | 511, 1%, 1/8W | RN60C5110F |
| R7 | 162, 1%, 1/4W | RN65C1620F |
| R8 | 51.1, 1%, 1/4W | RN65C51R1F |
| R9 | 19.6K, 1/4W, | RN65C1962F |
| C1 | 2.2 μF | CS13B225K |
| C2 | 1 μF | CL33CN010MN |
| P1 | AN3102A 10SL-3P | |
| P2 | Amphenol 165-16 | Receptical Female |
| S1 | SPDT | MS35058-23 |
| S2 | PS100 | Centralab |
| J1 | U.S. Components | UPCR93-D22-T1 |
| J2 | " " | " |
| J3 | " " | " |
| J4 | " " | " |
| J5 | Cinch | 2501036170 |
| J6 | " | " |
| J7 | " | " |
| J8 | Custom made connector | |

## PARTS LIST
## METER BOX

| | | | |
|---|---|---|---|
| C1 | 1μF, 35V | | |
| R1 | 464K | | RN70C4643F |
| R2 | 100K | | RN65C1001F |
| R3 | 3.16K | | RN65C3163F |
| R4 | 133K | | RN65C133F |
| R5 | 4.87K | | RN65C4371F |
| J1 | Banana Jack, Black | | |
| J2 | " " Red | | |
| J3 | " " Black | | |
| J4 | " " Red | | |
| P1 | Amphenol 165-16 | Receptical Female | |
| M1 | Ammeter 0-100μA, 2 1/2" Dia., | General Electric, 152011 MJMG | |
| M2 | Ammeter 0-100μA, 2 1/2" Dia., | General Electric, 152011 MJMG | |
| M3 | Voltmeter 0-5V, 2 1/2" Dia., | General Electric, 152111 DRDR | |
| S1 | DPST Toggle | | MS35039-22 |
| S2 | DPST Toggle | | MS35039-22 |

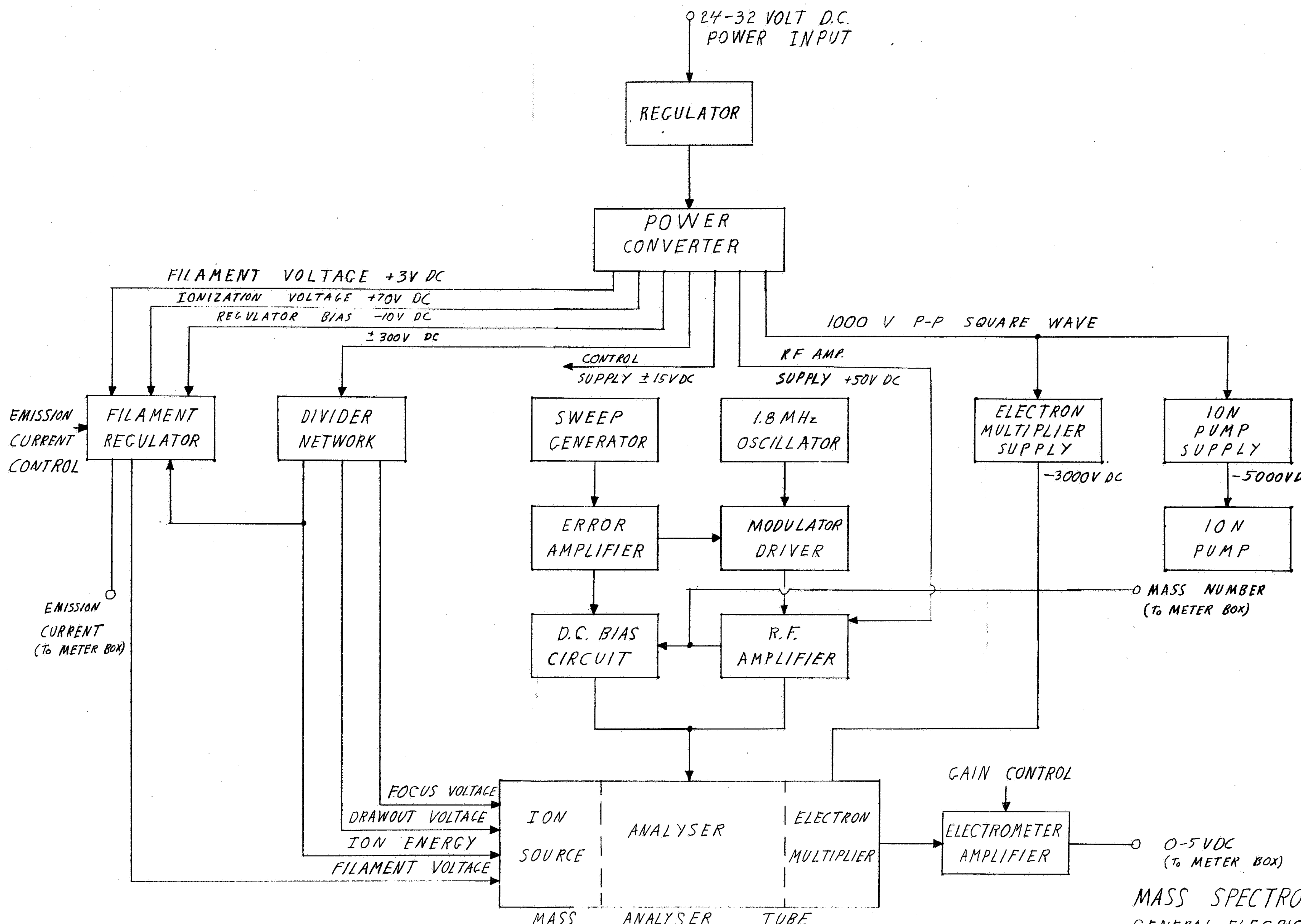
PARTS LIST
CABLES

2 - Amphenol 165-16 Plug Male

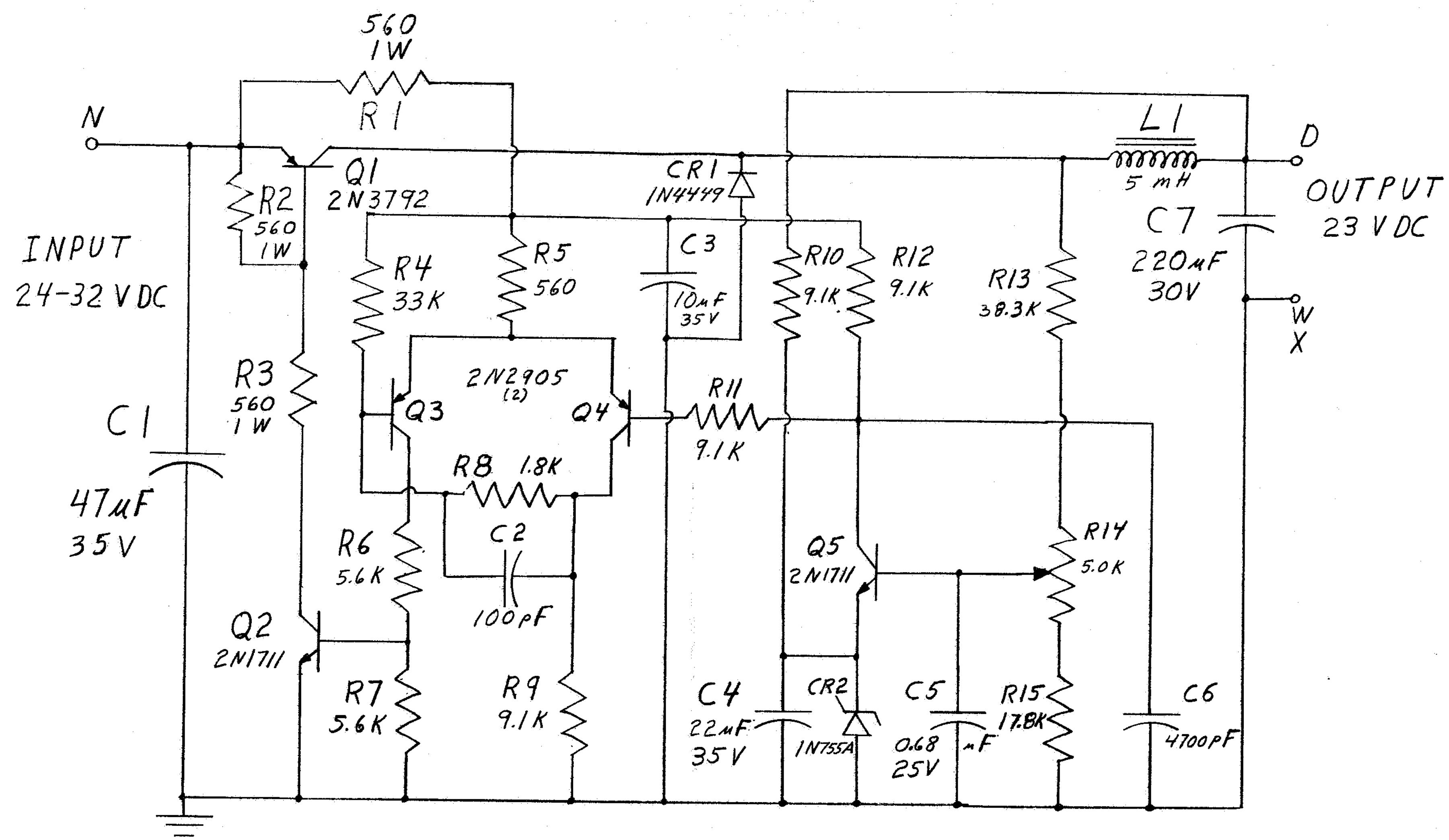
# PART VI

## DRAWINGS

FOLDOUT FRAME




MASS SPECTROMETER
GENERAL ELECTRIC CO
APOLLO SYSTEMS DEPT
DAYTONA BEACH FLORIDA
SK-56137-4-382-101
REV 1

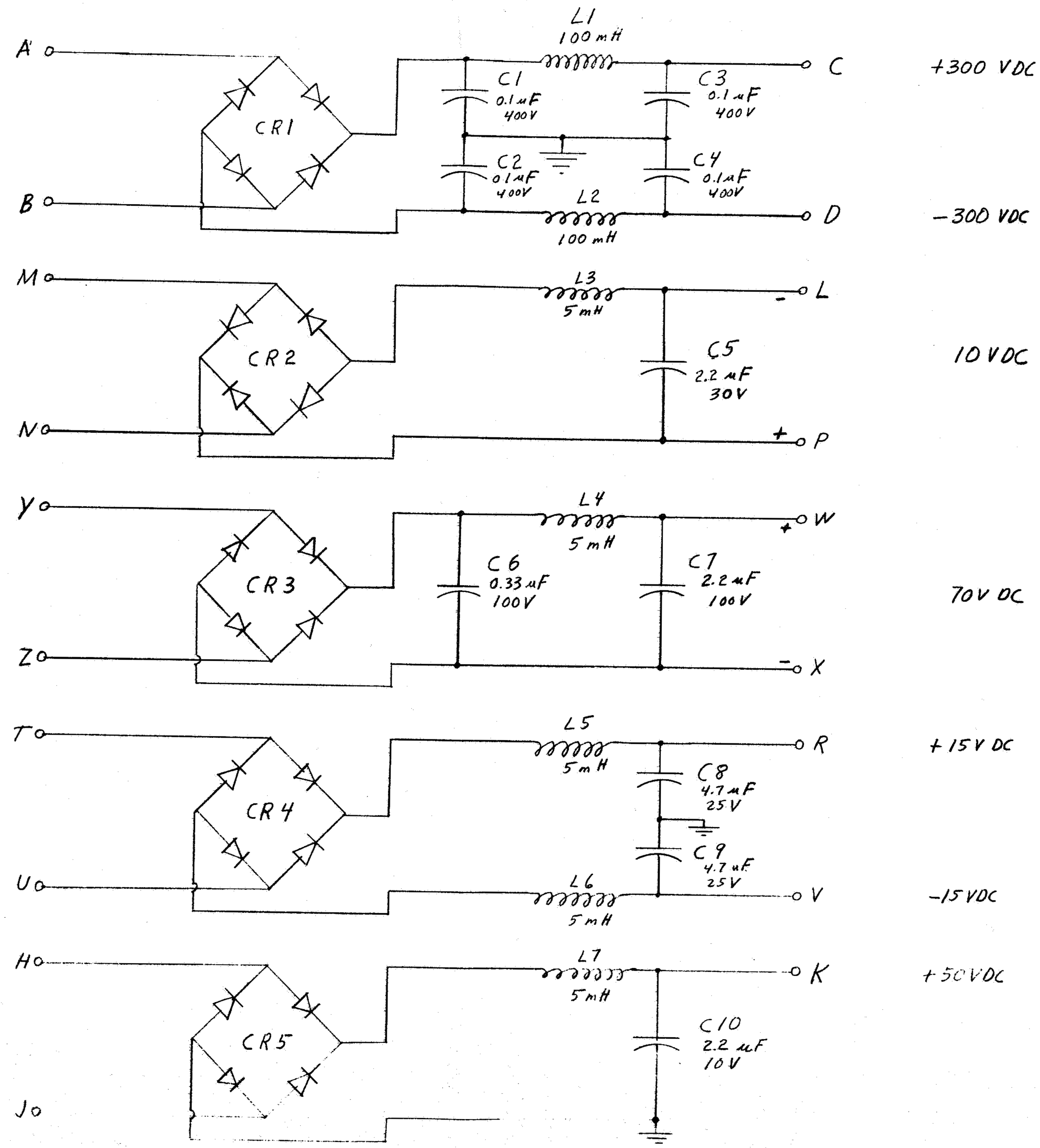



BOARD MS-1
REGULATOR

General Electric Co.
Apollo Systems Dept.
DayTona Beach, Florida

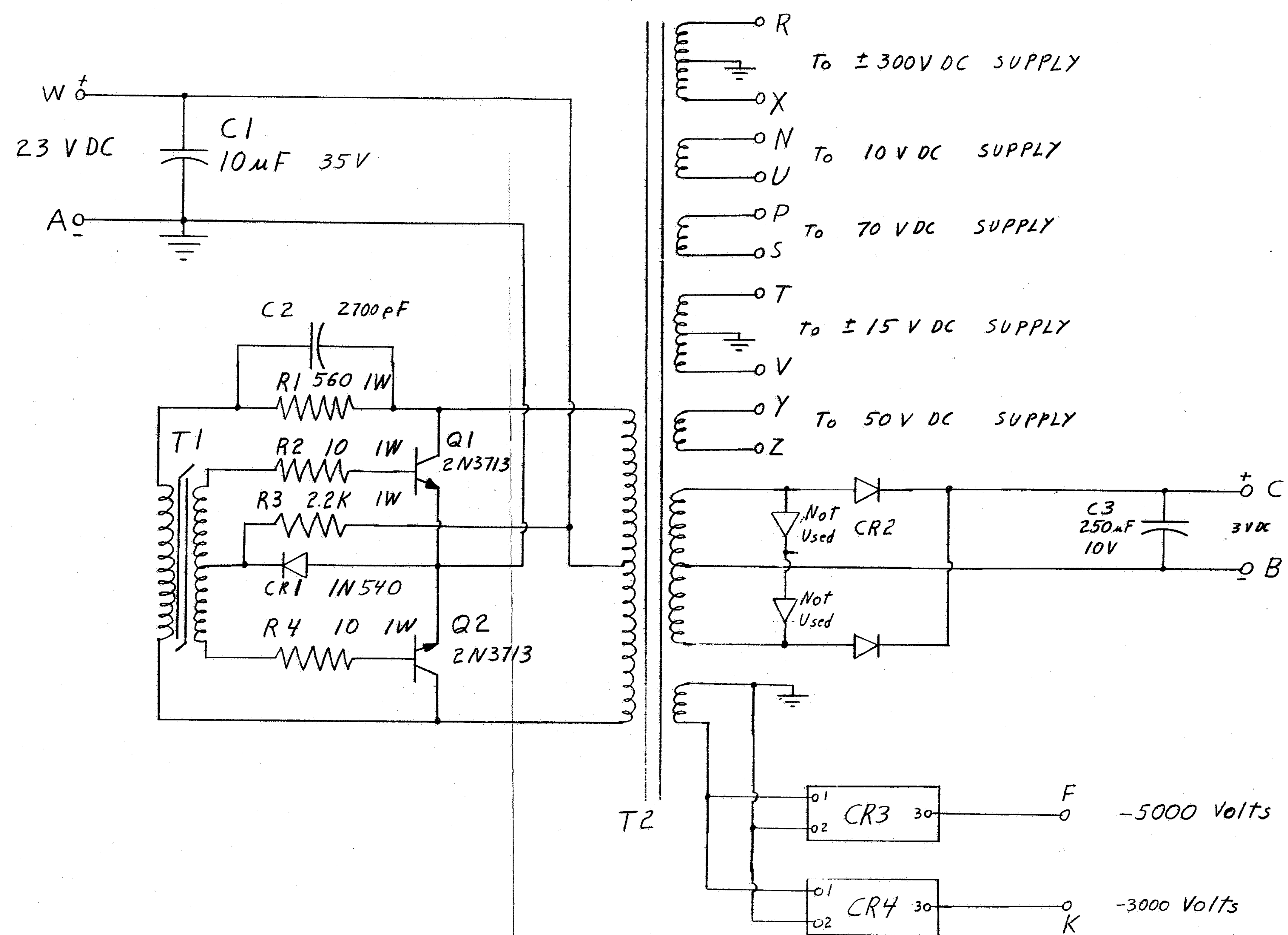
Shannon Little March 30, 1968
SK-56137-4-382-102
Rev. 1

FOLDOUT FRAME

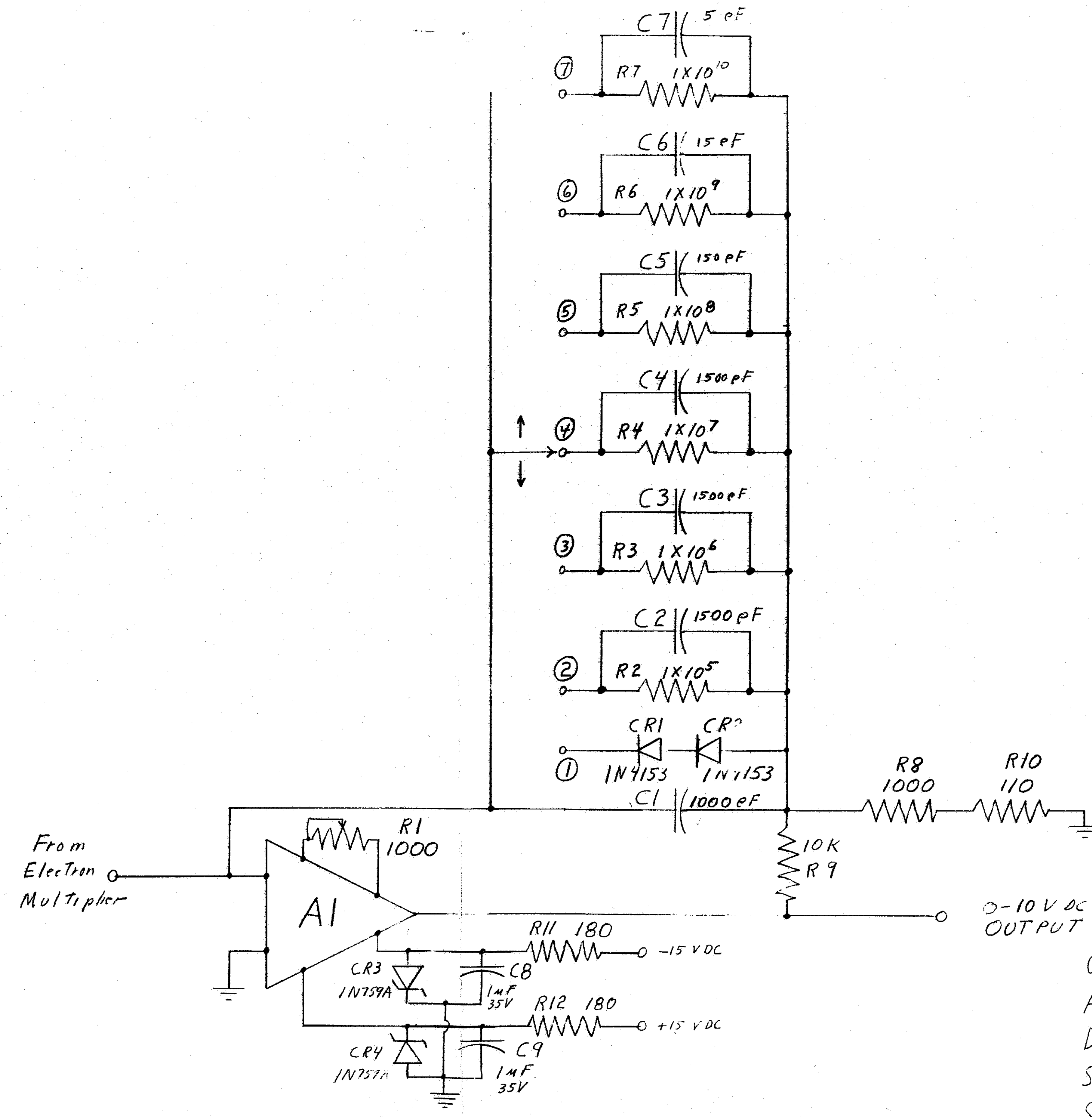



BOARD MS-2
POWER CONVERTER II

GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT.
DayTona Beach, Florida
Shannon Little April 8, 1968
SK-56137-4-382-103
Rev. 1



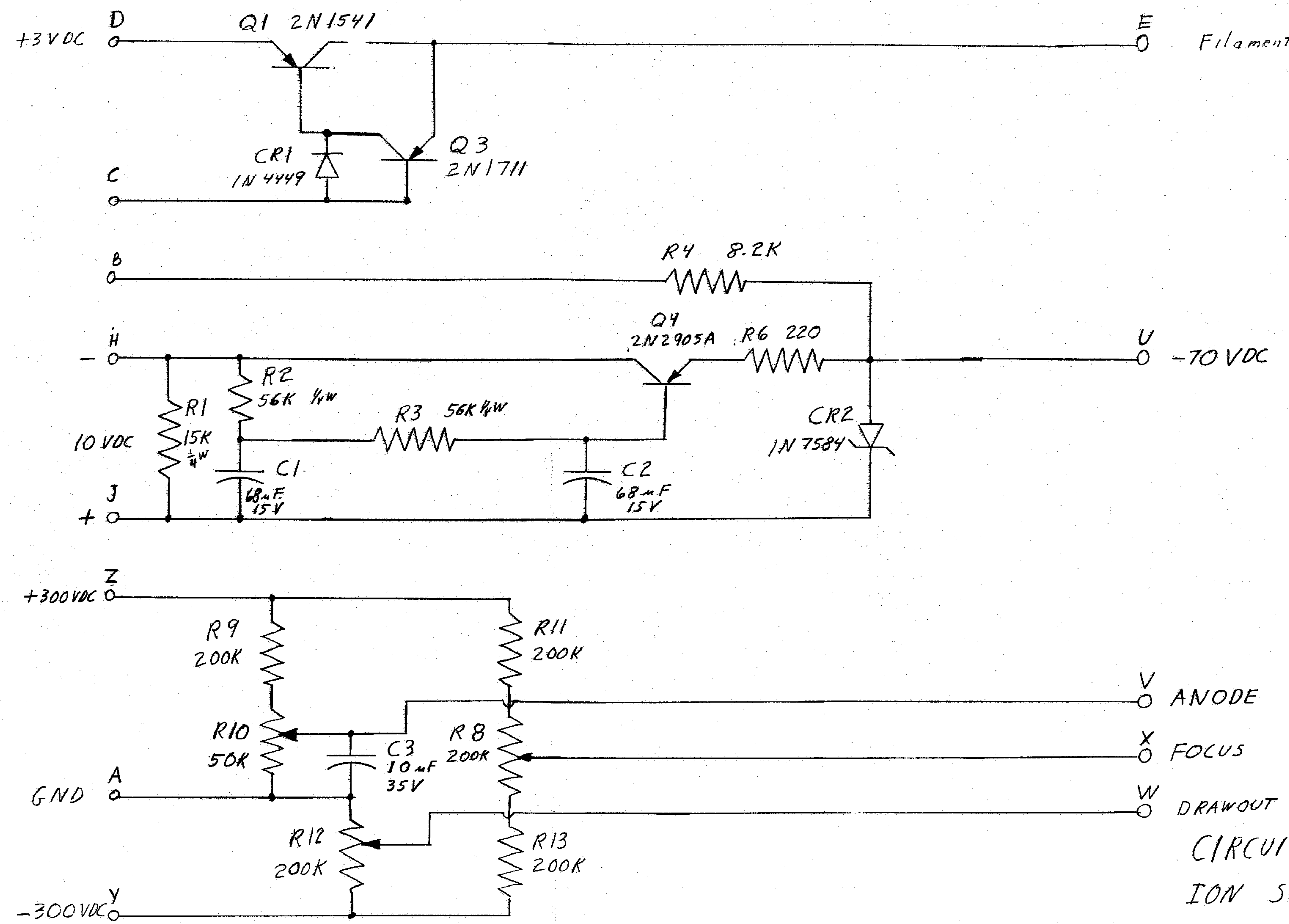

BOARD MS-3
POWER CONVERTER I
GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT.
Daytona Beach, Florida
Shannon Little April 8, 1968
SK-56137-4-382-104
Rev 1




# ELECTROMETER AMP.

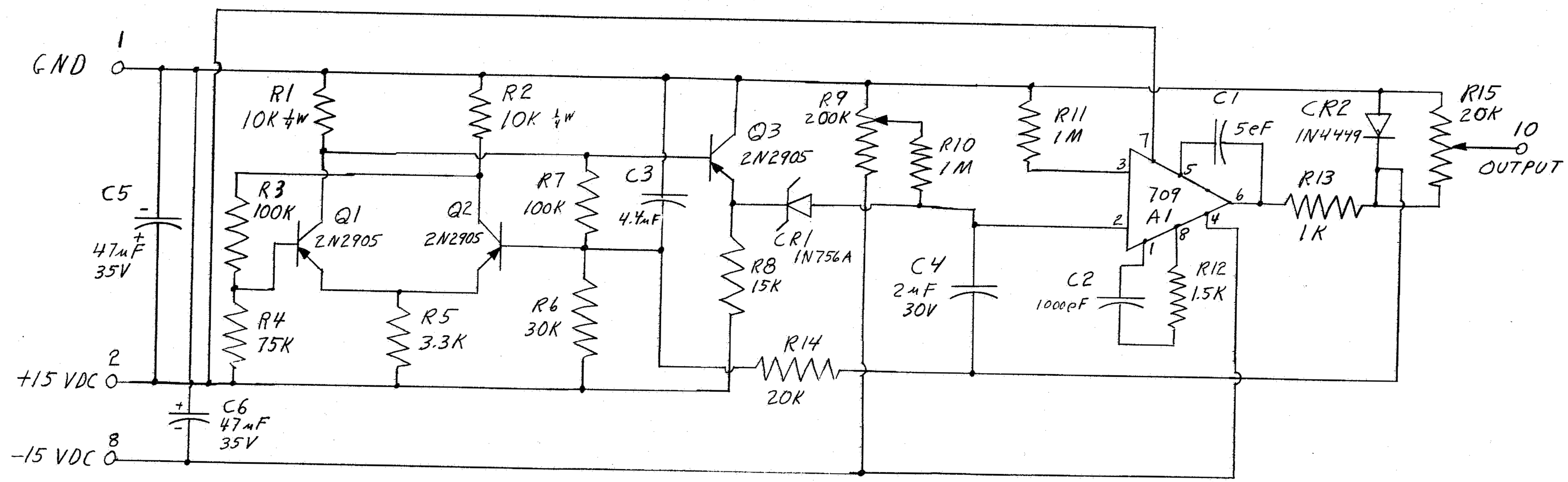
GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT.
Daytona Beach, Florida
Shannon Little April 8, 1968
SK-56137-4-382-105
Rev. 1

FOLDOUT FRAME




CIRCUIT BOARD MS-5
ION SOURCE CONTROL

GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT.
Daytona Beach, Florida
Shannon Little April 8, 1968
SK 56137 4-382-106

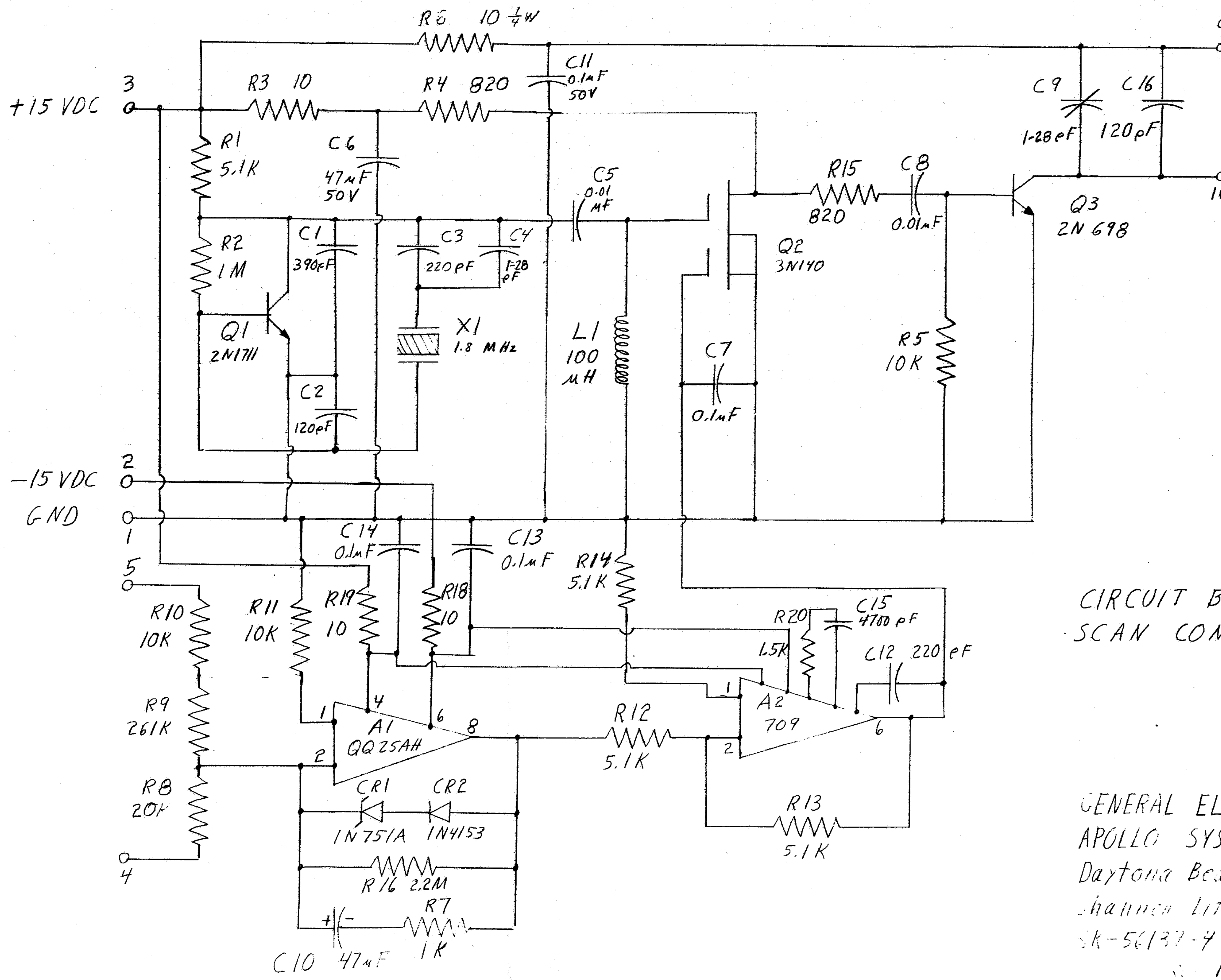



CIRCUIT BOARD MS-6
SWEEP GENERATOR

GENERAL ELECTRIC CO
APOLLO SYSTEMS DEPT.
Daytona Beach, Florida
Shannon Little April 8, 1968
SK-56137-4-39?-1?7
Rev. 1

FOLDOUT FRAME

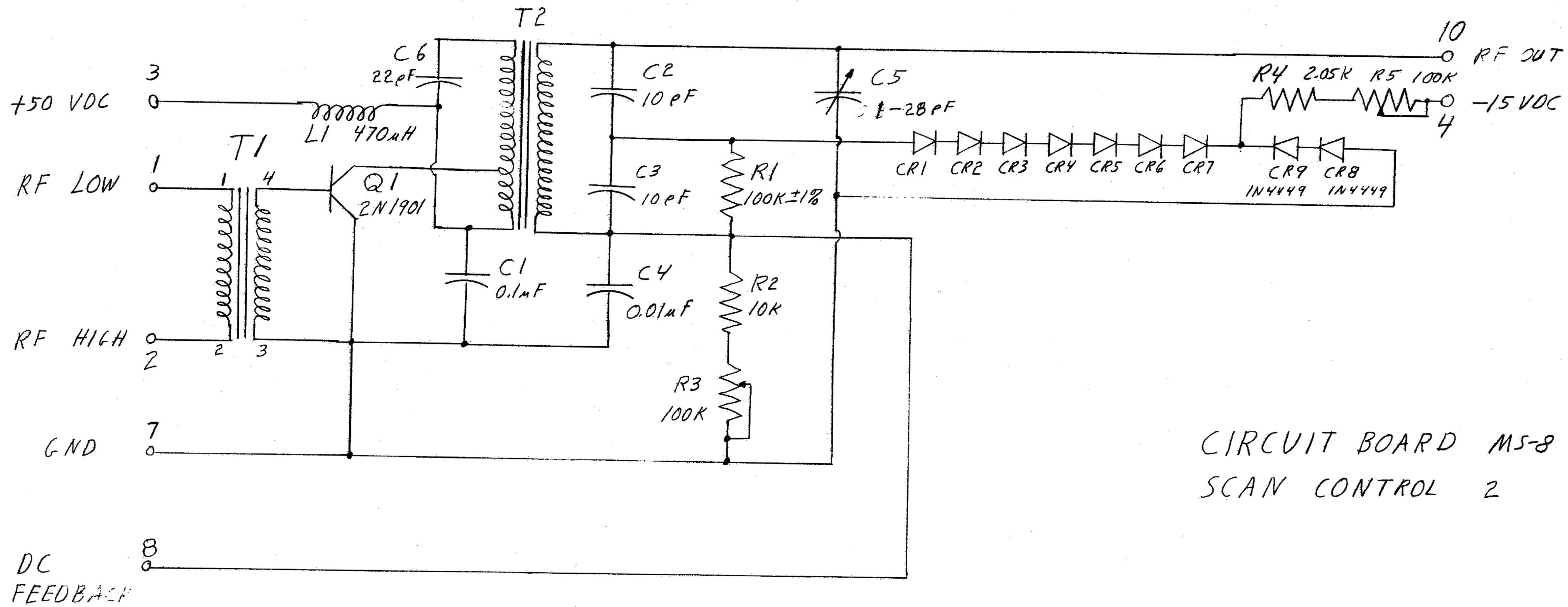
FOLDOUT FRAME




CIRCUIT BOARD MS-7
SCAN CONTROL 1

GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT.
Daytona Beach, Florida
Shannon Little April 8, 1968
SK-56137-4-392-1CS
1

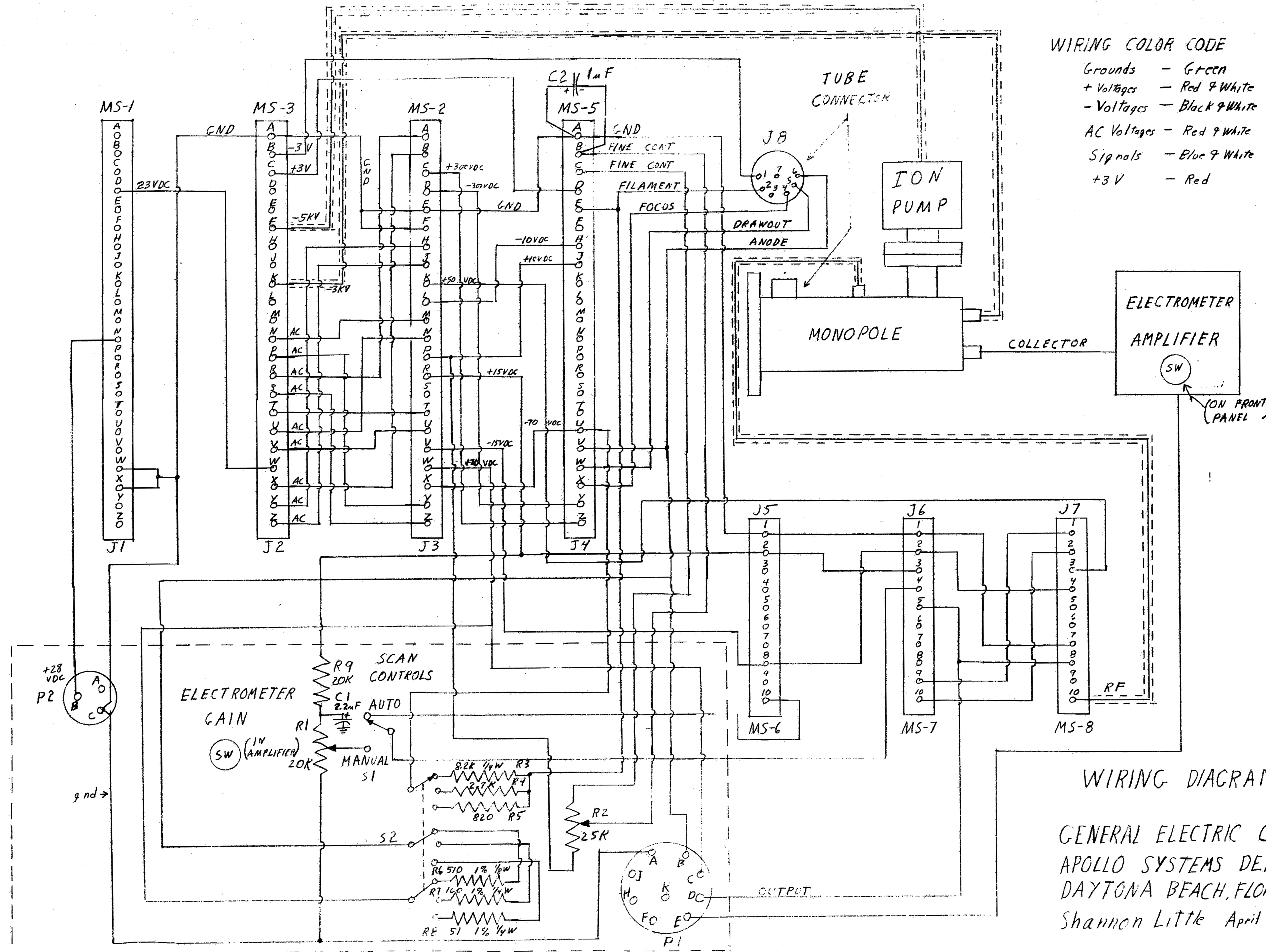
FOLDOUT FRAME




CIRCUIT BOARD MS-8
SCAN CONTROL 2

GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT.
Daytona Beach, Florida
Shannon Little April 8, 1968
SK-56137-4-382-1C9
Rev. 2

FOLDOUT FRAME




WIRING COLOR CODE

| | | |
|---|---|---|
| Grounds | - | Green |
| + Voltages | — | Red & White |
| - Voltages | — | Black & White |
| AC Voltages | - | Red & White |
| Signals | - | Blue & White |
| +3 V | - | Red |

WIRING DIAGRAM

GENERAL ELECTRIC CO
APOLLO SYSTEMS DEPT
DAYTONA BEACH, FLORIDA
Shannon Little April 9, 1968

SK-56137-4-332-110
REV 1

FOLDOUT FRAME

FOLDOUT FRAME

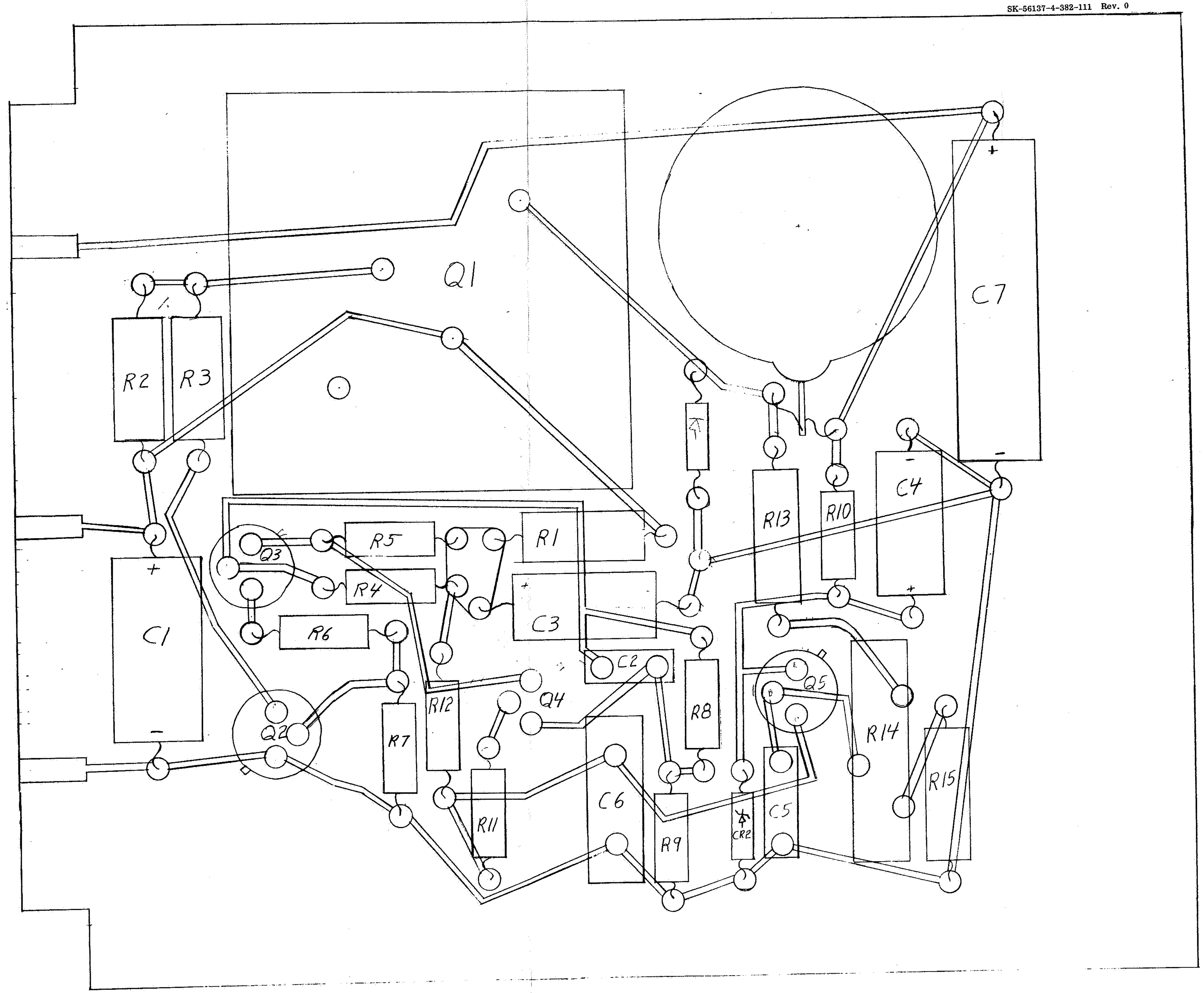
CIRCUIT BOARD MS-1
REGULATOR

GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT.
DAYTONA BEACH, FLORIDA

Shannon Little April 10, 1968

SK-56137-4-382-111 Rev. 0

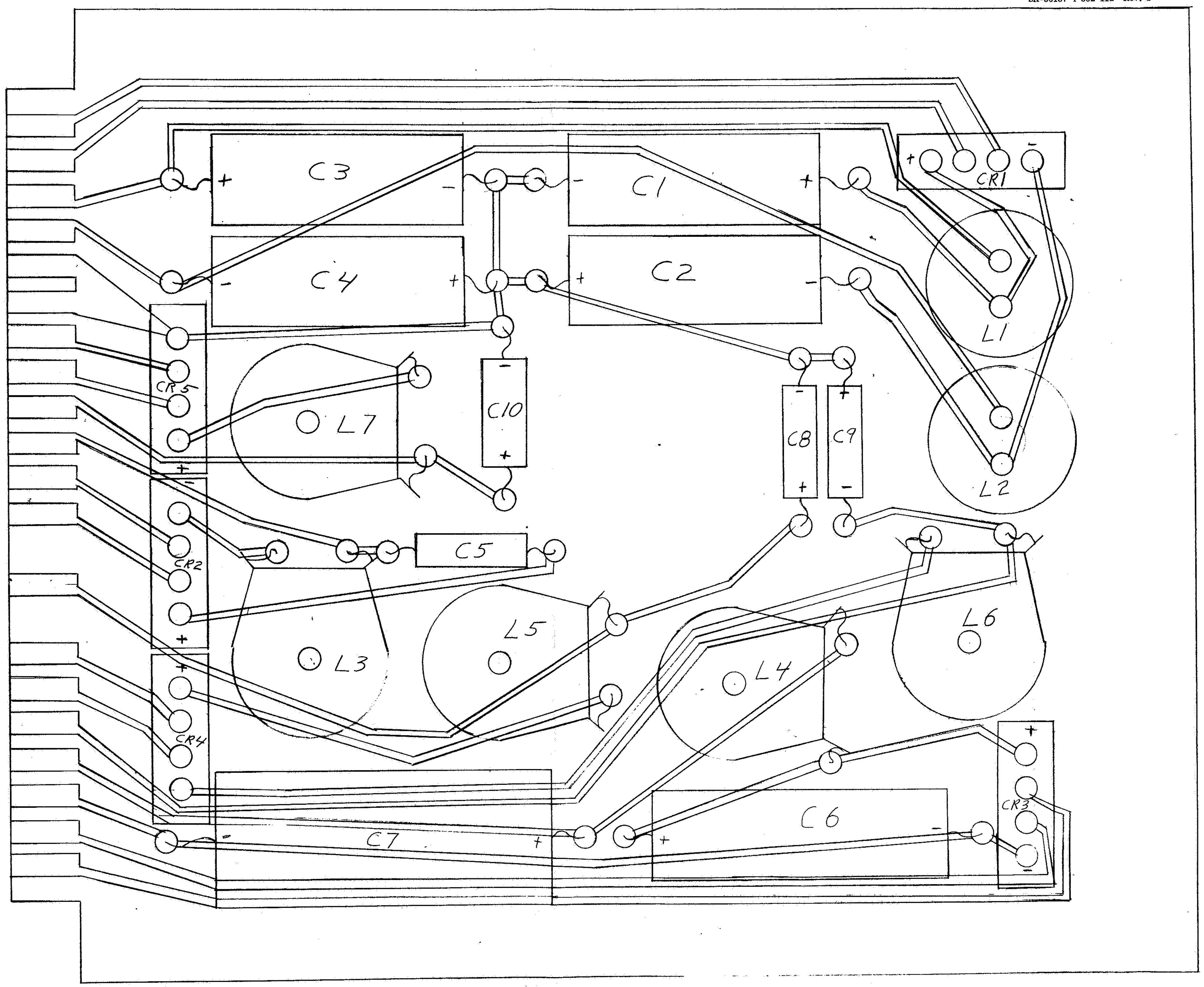
NOTES:
1. Component side view.
2. All printed conductors on other side unless crosshatched.



FOLDOUT FRAME

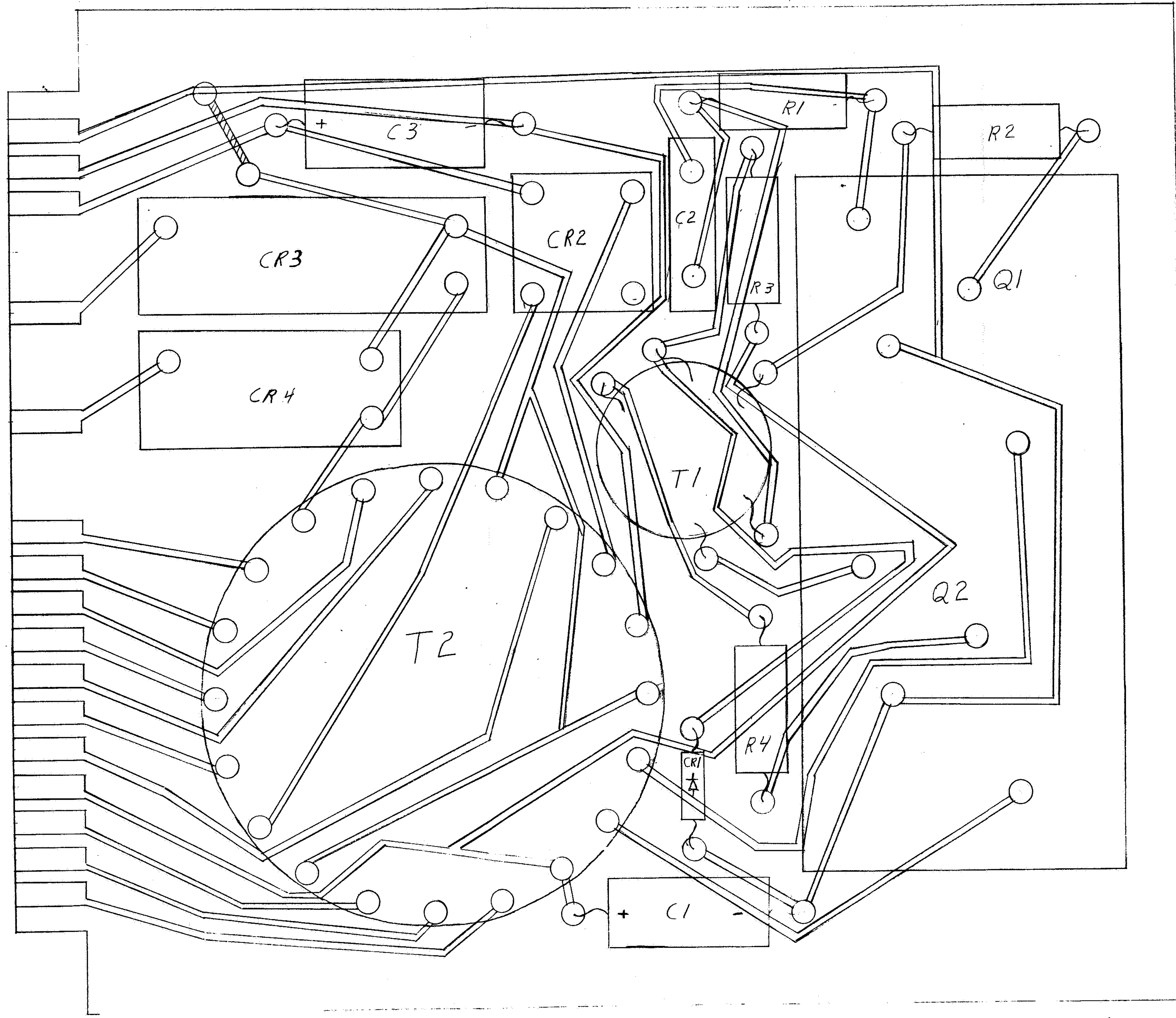
NOTES:
1. Component side view.
2. All printed conductors on other side unless crosshatched.

CIRCUIT BOARD MS-2
POWER CONVERTER II
GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT.
DAYTONA BEACH, FLORIDA
Shannon Little April 10, 1968
SK-56137-4-382-112 Rev. 1



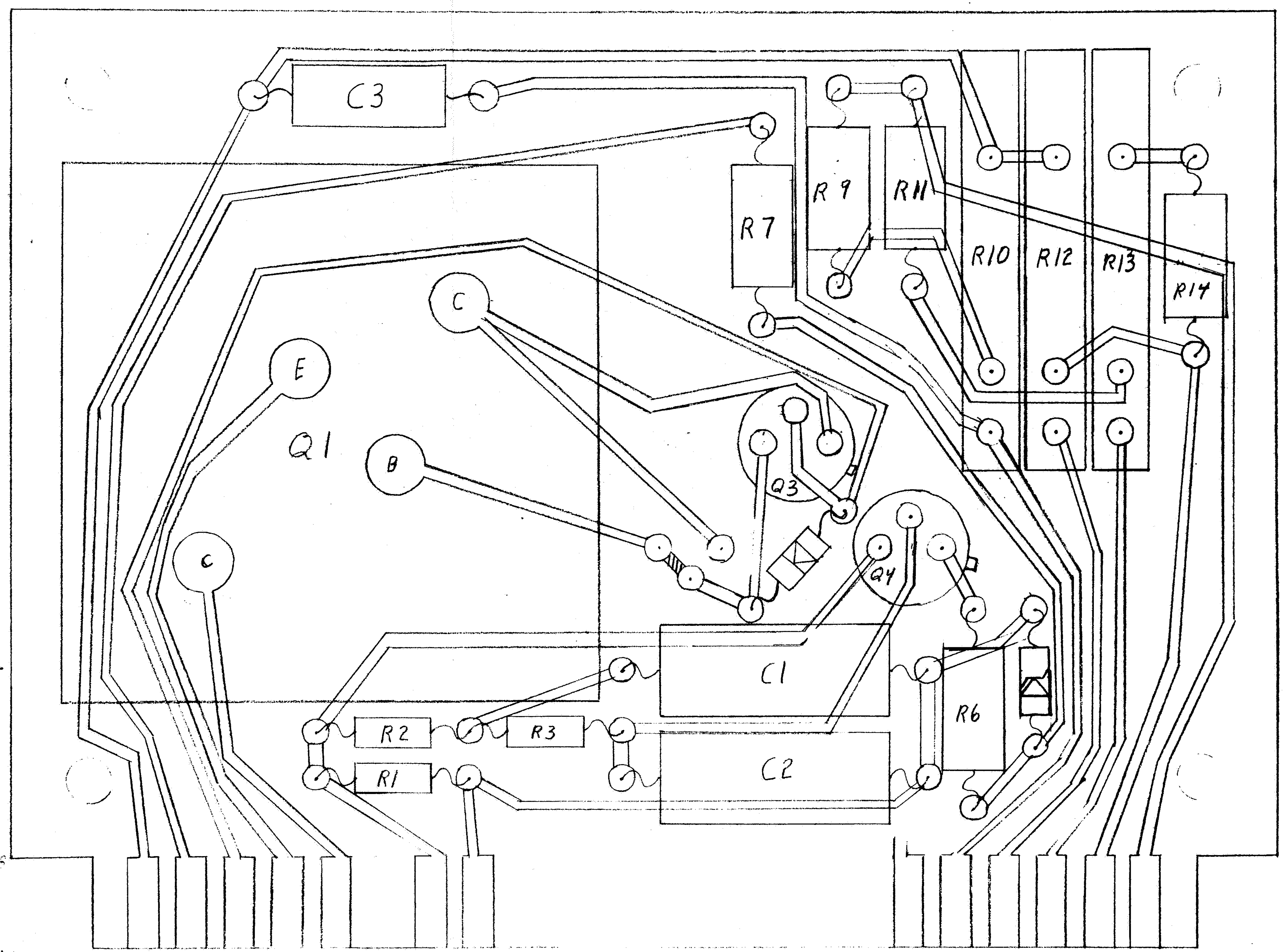
NOTES:
1. Component side view.
2. All printed conductors on other side unless crosshatched.

CIRCUIT BOARD MS-3
POWER CONVERTER I
GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT.
DAYTONA BEACH, FLORIDA
Shannon Little April 10, 1968
SK-56137-4-382-113 Rev. 0



FOLDOUT FRAME

FOLDOUT FRAME




NOTES:
1. Component Side View
2. All printed Conductors on other side unless cross hatched.

CIRCUIT BOARD MS-5
ION SOURCE

GENERAL ELECTRIC CO
APOLLO SYSTEMS DEPT
DAYTONA BEACH, FLORIDA

Shannon Little April 9, 1968

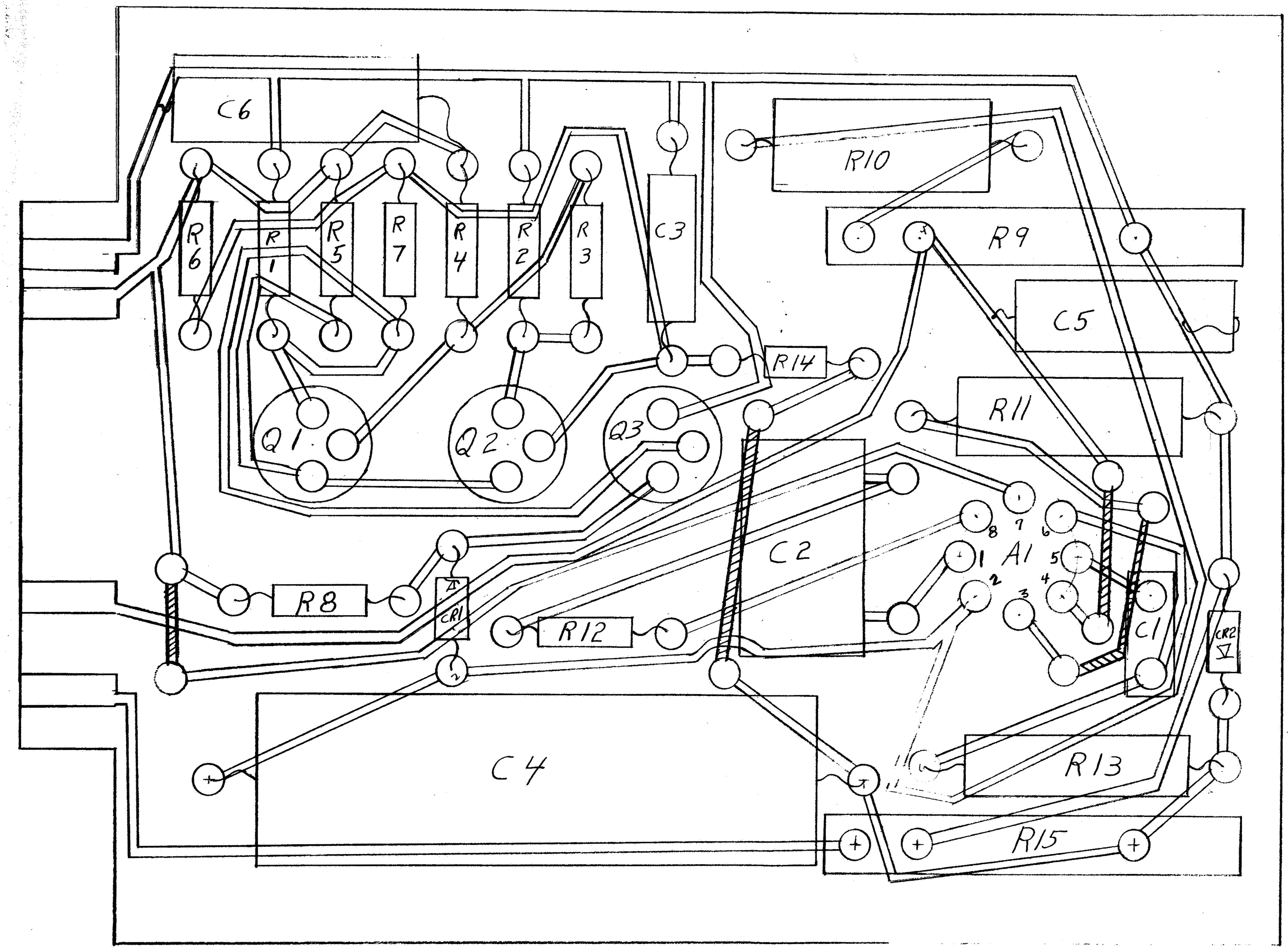
SK-56137-4-382-114

REV. 1 Delete [illegible]

FOLDOUT FRAME

Sweep Generator

FOLDOUT FRAME




NOTES:
1. Component Side View.
2. All printed conductors on other side unless cross hatched.

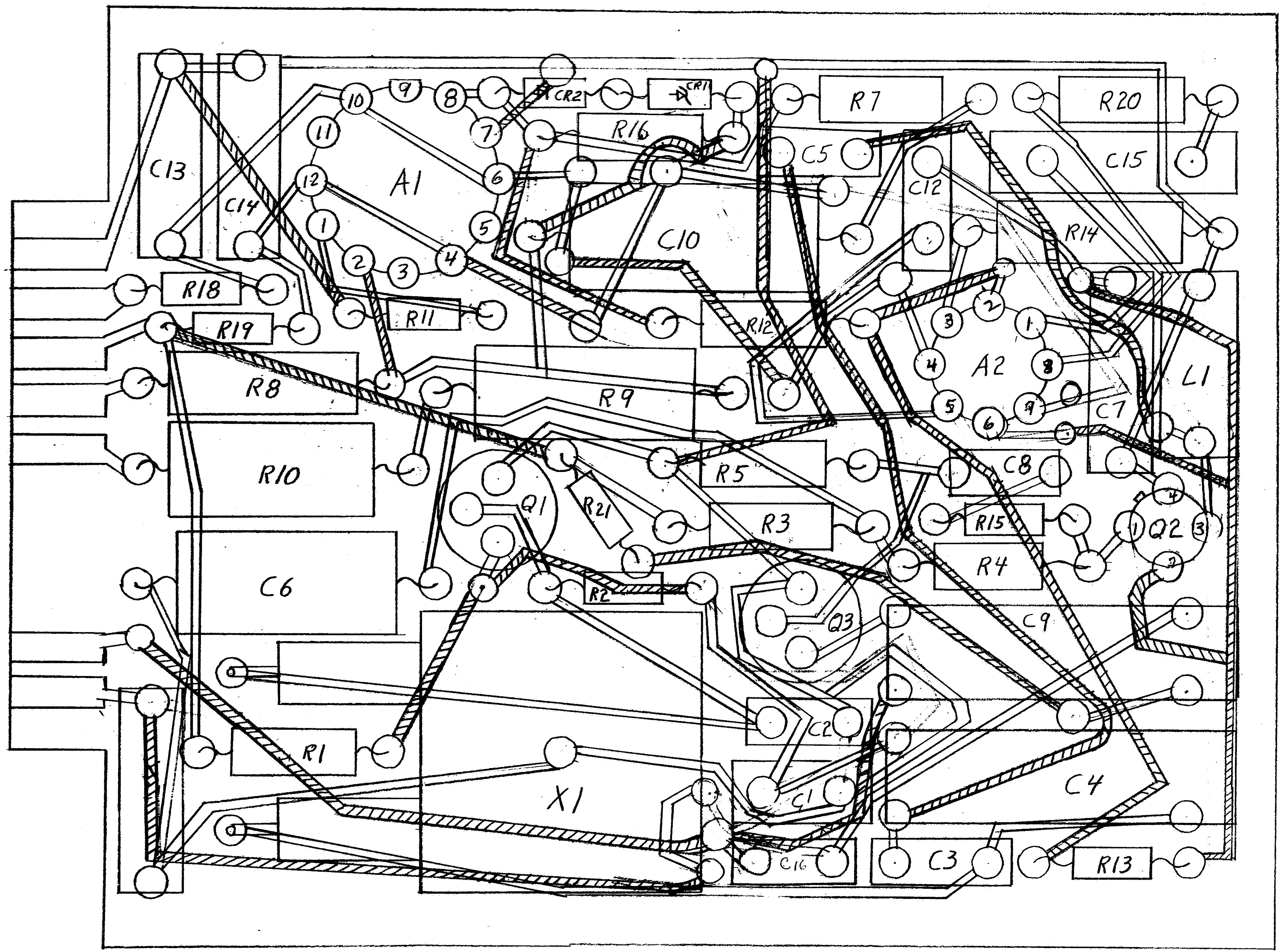
CIRCUIT BOARD
MS-6

SWEEP GENERATOR

GENERAL ELECRIC CO
APOLLO SYSTEMS DEPT
DayTona Beach, Florida
Shannon Little April 8, 1968
SK-56137-4-382-115

REV. 1

FOLDOUT FRAME




NOTES:
1. Component side view.
2. All printed conductors on other side unless cross hatched.

CIRCUIT BOARD MS-7
SCAN CONTROL 1

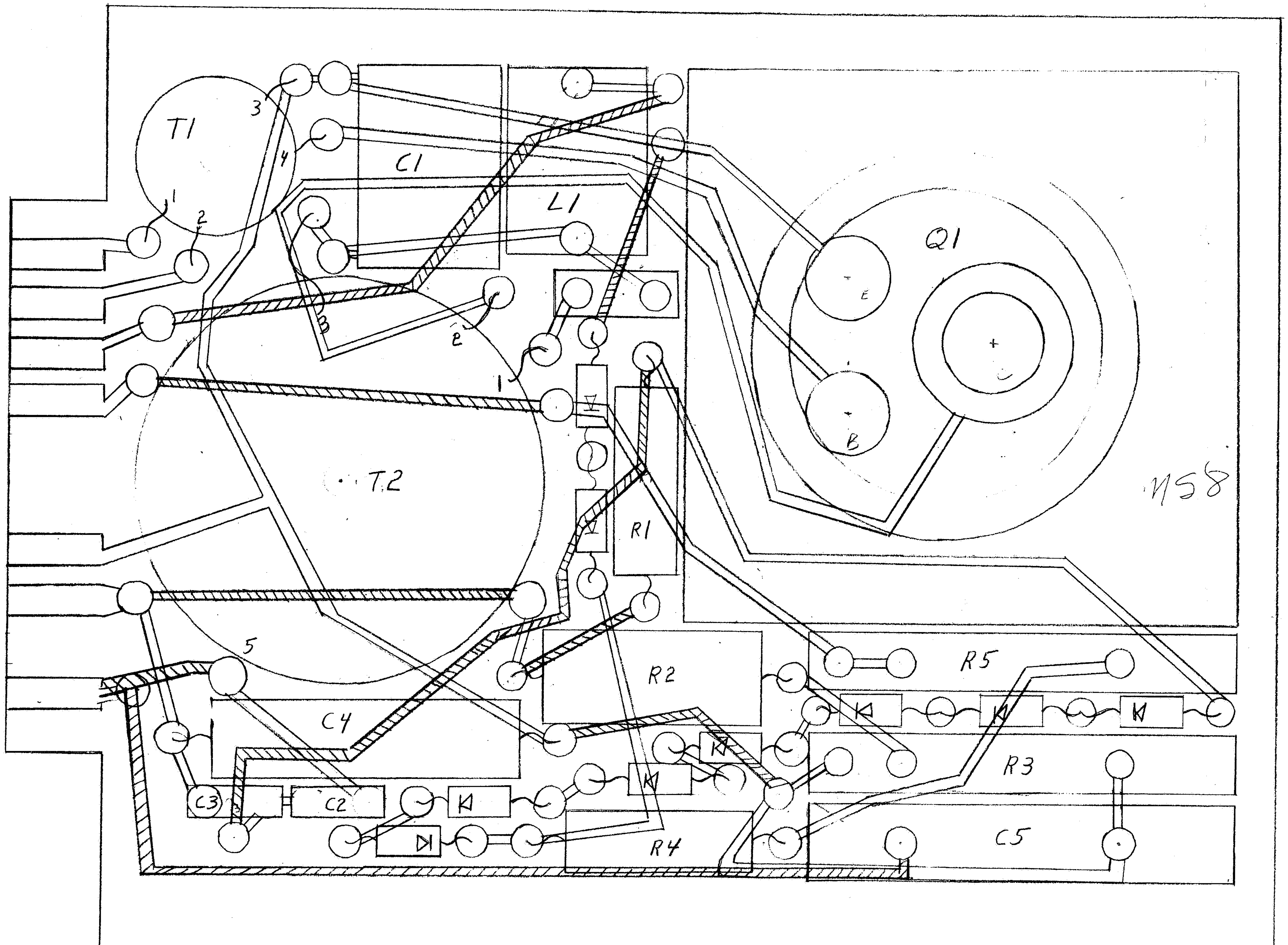
GENERAL ELECTRIC CO
APOLLO SYSTEMS DEPT
DAYTONA BEACH, FLORIDA

Shannon Little Apr 19, 1968

SK-56187 -4-382-116
Rev O

FOLDOUT FRAME

FOLDOUT FRAME




NOTES:
1. Component Side View
2. All printed conductors on other side unless cross hatched.

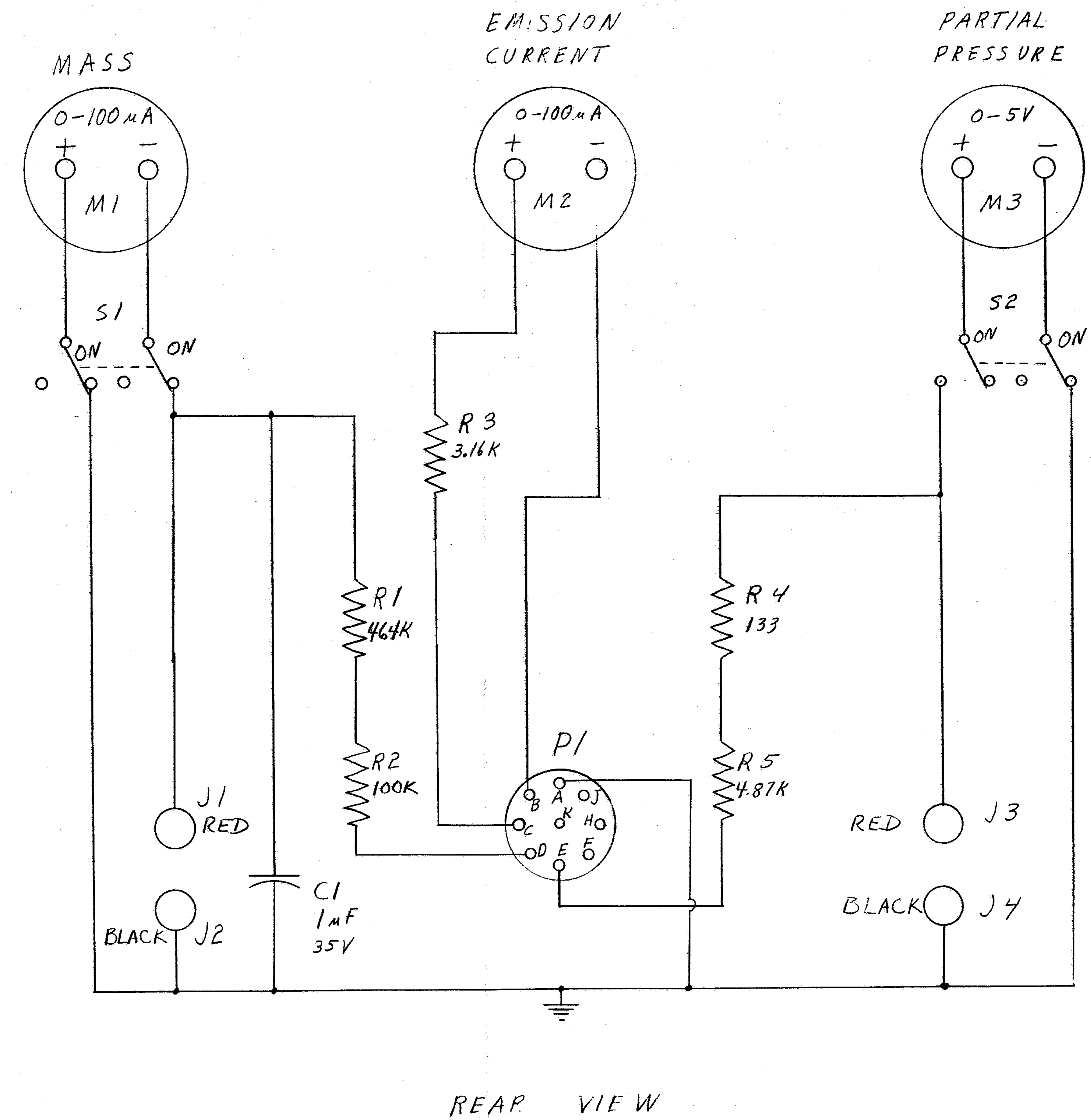
CIRCUIT BOARD MS-8
SCAN CONTROL 2

GENERAL ELECTRIC CO
APOLLO SYSTEMS DEPT
DAYTONA BEACH, FLORIDA

Shannon Little April 9, 1968

SK-56137-4-382-117

REV 1




METER BOX
PANEL WIRING

GENERAL ELECTRIC CO.
APOLLO SYSTEMS DEPT
DAYTONA BEACH, FLORIDA

SHANNON LITTLE
APRIL 24, 1968

SK-56137-4-382-118
REV. 1
REV. 2 Changed $R_1$ & $R_2$